

**NASA
Technical
Memorandum**

NASA TM - 108469

METRICATION IN A GLOBAL ENVIRONMENT

By J. Aberg

Systems Analysis and Integration Laboratory
Science and Engineering Directorate

October 1994



National Aeronautics and
Space Administration

George C. Marshall Space Flight Center

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. BACKGROUND	2
A. Origin of Measurement Systems	2
B. The English System	3
C. The Metric System	4
III. GLOBAL CONVERSION EXPERIENCE	7
A. General	7
B. British Experience	7
C. Australian Experience	9
D. Canadian Experience	11
IV. U.S. CONVERSION EXPERIENCE	12
A. General	12
B. Education	13
C. Construction	14
D. Transportation	18
V. LOCAL EXPERIENCE	20
A. Government	20
B. City of Huntsville	23
C. Educational Institutions	28
VI. SPECIAL CONVERSION ITEMS	29
A. Standardization	29
B. Machine Shop Conversion	31
C. International Paper Sizes	35
D. Training	36
VII. FUTURE OF METRICATION	39
BIBLIOGRAPHY	40
APPENDIX A – REMARKS BY THE HONORABLE GEORGE E. BROWN, JR.	41
APPENDIX B – PUBLIC AWARENESS	45
APPENDIX C – CONVERTING DIMENSIONS	53

LIST OF ILLUSTRATIONS

Figure	Title	Page
1.	What is metrication?	2
2.	Why metrication?	2
3.	Inch/foot definitions	3
4.	Yard definition	4
5.	Inch-pound versus SI units.....	5
6.	International organization structure	6
7.	The modern metric system	6
8.	Definition of kilogram	8
9.	MSFC metric pilot project	14
10.	Site plan.....	15
11.	Floor plan	16
12.	Elevation	17
13.	Design approach.....	18
14.	Conversion target dates	19
15.	Philosophy of conversion.....	19
16.	Structure of conversion	20
17.	The Renard system	23
18.	Basic series of preferred numbers	24
19.	Modified series of preferred numbers	25
20.	“Type reduction”	26
21.	NASA goes metric	26
22.	“Metric power”	27
23.	Power ratings.....	27
24.	50-km speed limit.....	28
25.	International standards organization	30

LIST OF ILLUSTRATIONS (Continued)

Figure	Title	Page
26.	Partial membership structure	30
27.	ISO/Technical Committee TC20	31
28.	Milling machine	32
29.	Lathe	33
30.	Conversion dial—modification	33
31.	Simple conversion modification	34
32.	Accurate conversion modification	34
33.	International paper, ISO A-series	35
34.	International paper dimensions	36
35.	U.S. MA metric materials	37
36.	Training aids	38
37.	“The black hole”	39

TECHNICAL MEMORANDUM

METRICATION IN A GLOBAL ENVIRONMENT

I. INTRODUCTION

Huntsville! "The city where the sky is not the limit;" the city that produced the first western satellite 36 years ago; the city which arranged the first lunar landing 25 years ago; the city which is now listed as "one of the top seven economic hotspots in the U.S." (*U.S. News and World Report*), and the city where progress is ruled by high technology. Yet the global aspects of metrication have not been fully accepted by local industry and Government institutions. However, there are signs of interest, and products manufactured for export are being developed using the metric system of measurement. In January 1951 when I arrived at the Huntsville railroad depot, the city was a small southern city with cotton being the main product. Cotton brokers were housed around the square, and Huntsville enjoyed the reputation of "watercress capital of the world." Later, as metrication began to be accepted, Huntsville became the "space capital of the universe," and "Rocket City U.S.A." The town soon grew into a sophisticated high-tech town with a global reputation. Over 100 different nationalities were represented in Huntsville, which grew from 16,000 to 72,000 inhabitants in 10 years.

The technical people who arrived from all states and other parts of the world recognized early that the system of measurements which had served the cotton trade so well did not apply to rockets, space flight, and other high-tech business ventures. The archaic inch-pound system had to be abandoned because scientists and engineers of Huntsville worked with counterparts from all over the world. Several of the Army/National Aeronautics and Space Administration (NASA) team members, including Dr. Wernher von Braun, wanted to convert to the metric system. Some acceptance of metrication began in the 1950's. In the 1960's, many Army Ballistic Missile Agency (ABMA) and NASA employees served on national study groups and committees to develop metric transition plans, conversion tables, reports, and instruction material.

The word "metrication" is a relatively new term coined by the British during their conversion activities between 1965 and 1975. Metrication is defined as "any act that tends to increase the use of the metric system of measurement." Figure 1 presents two separate, distinct meanings of metrication: "soft conversion" and "hard conversion." The soft conversion changes inch-pound units to metric equivalents (no physical product changes), and the hard conversion redesigns the product to a metric modules product.

"Why metrication?" Because metric is the law and international competition demands metric (fig. 2). The concept of metrication and its global aspects were superbly presented by the honorable George E. Brown at the National Metric Conference in the fall of 1993. In his paper, "Metrication Now for America's Economic Competitiveness," he suggested that we ask ourselves why we prefer "the Yugo of measurement when the Cadillac is ours for the asking." He also said that "metrication is both essential and inevitable, and the sooner we face this fact, the better off we will be."

A copy of Representative Brown's address is included as appendix A. For further information regarding this paper, contact: The Honorable George E. Brown, Jr., Chairman, Committee on Science, Space, and Technology, Suite 2320 Rayburn House Office Building, Washington, DC 20515, (202) 225-6371.

What is Metrication?

Two separate, distinct meanings:

1. Change measurement language to International System of Units (SI)
 - SOFT CONVERSION
2. Change engineering or product standards from inch-pound modules to metric modules or modes.
 - HARD CONVERSION

Figure 1. What is metrication?

Why Metrication?

- Metric is the law.
- International competition demands metric.

Figure 2. Why metrication?

II. BACKGROUND

A. Origin of Measurement Systems

Primitive societies needed rudimentary measures for many tasks; constructing dwellings, developing maps, making clothing, and bartering for food and raw materials. Early Babylonian and Egyptian records and the Bible indicate that linear units were the first units of measure devised by men. The most important were the "cubit" and the "digit." The cubit was derived from the length of the forearm. The digit represented the width of the finger. Other units were the foot, the palm, the "great span" (the maximum span between the thumb and the little finger), the "little span" (the distance between the outstretched forefinger and the thumb), and the "fathom" (the distance between a man's outstretched arms). Time was measured in periods of the Sun, Moon, and other heavenly bodies. As societies evolved, measurement units became more complex, and mathematics made it possible to create whole systems of measurement units for trade, land division, taxation, or scientific research.

The Roman linear units may be summarized briefly as follows: the Roman digit was equivalent to the Egyptian digit, and 16 digits made a Roman foot. But the foot was also subdivided into 12 parts called "unciae," which later became inches. Body parts were still used to define units. The Romans also retained the cubit which was subdivided into 24 digits, and this, in time, became the English yard, which is really a double cubit. For longer distances, the Romans used a unit of 5,000 feet which they called mille passus (1,000 paces) or a mile.

B. The English System

The English system of measurement, or the inch-pound system used in the U.S., is nearly the same as that brought by the colonists from England. The ancient "digit," "palm," "span," and "cubit" units have evolved into "inch," "foot," and "yard" through a complicated transformation not yet fully understood. In England, the inch was equivalent to the length of three barley corns, and one foot had 36 barley corns, round and dry, taken from the middle of the ear of barley, as shown in figure 3. The "yard" as a measure of length can be traced back to the early Saxon kings. They wore a sash which they also used as a convenient measuring device. Thus, the word "yard" comes from the Saxon "gird," meaning the circumference of a person's waist.

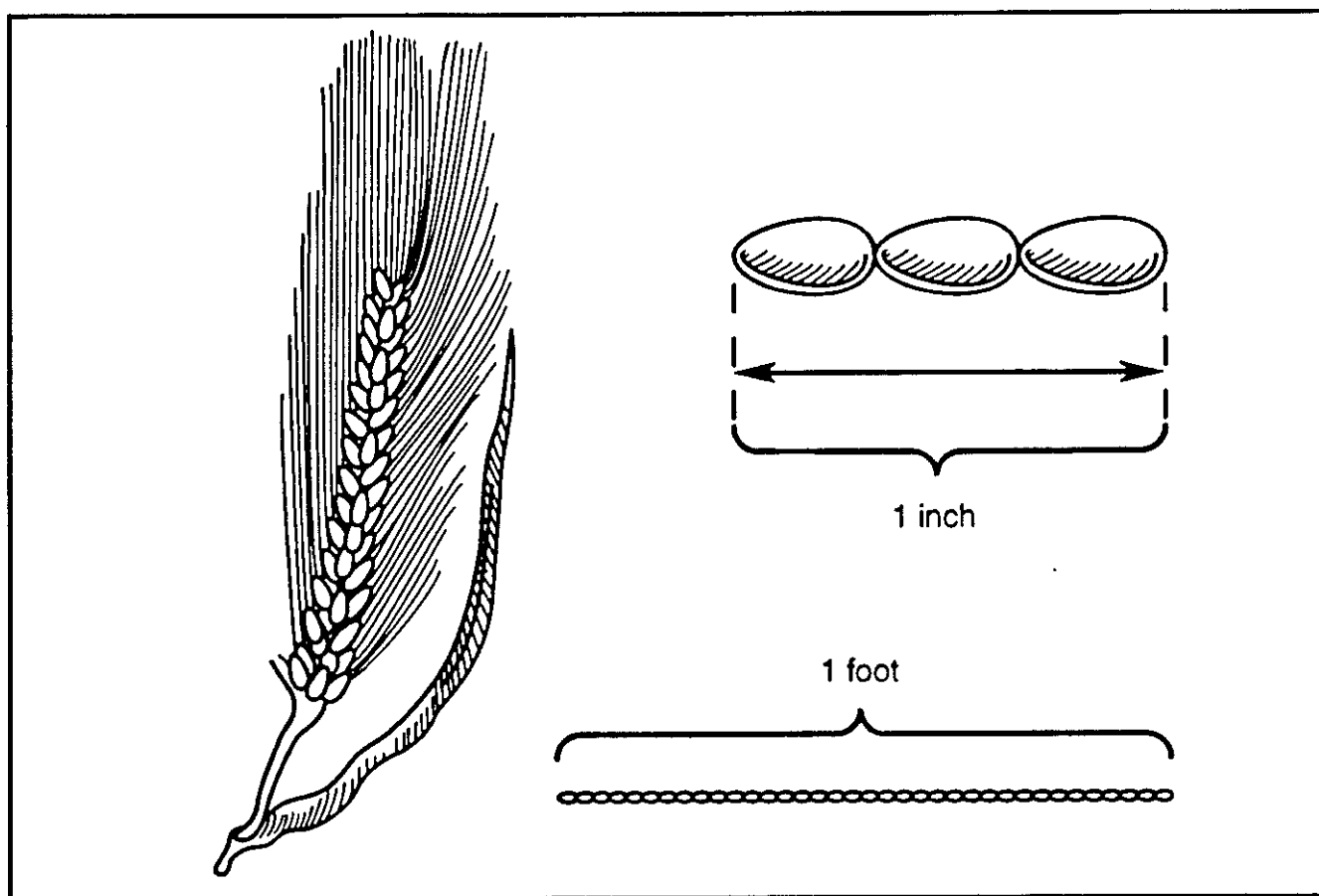


Figure 3. Inch/foot definitions.

Standardization of the various units and their combination into a loosely related system of measurement units sometimes occurred in fascinating ways. Through royal edicts, England achieved a

degree of standardization, e.g., tradition holds that King Henry I decreed that the yard should be the distance from the tip of his nose to the end of his thumb (fig. 4), and that Queen Elizabeth I declared, in the 16th century, that the Roman mile (5,000 feet) would be replaced by one of 5,280 feet, making the mile exactly 8 furlongs. The furlong (or furrow-long distance) had been established by early Tudor rulers as 220 yards. Thus, the relationship between furlong and mile became more convenient.

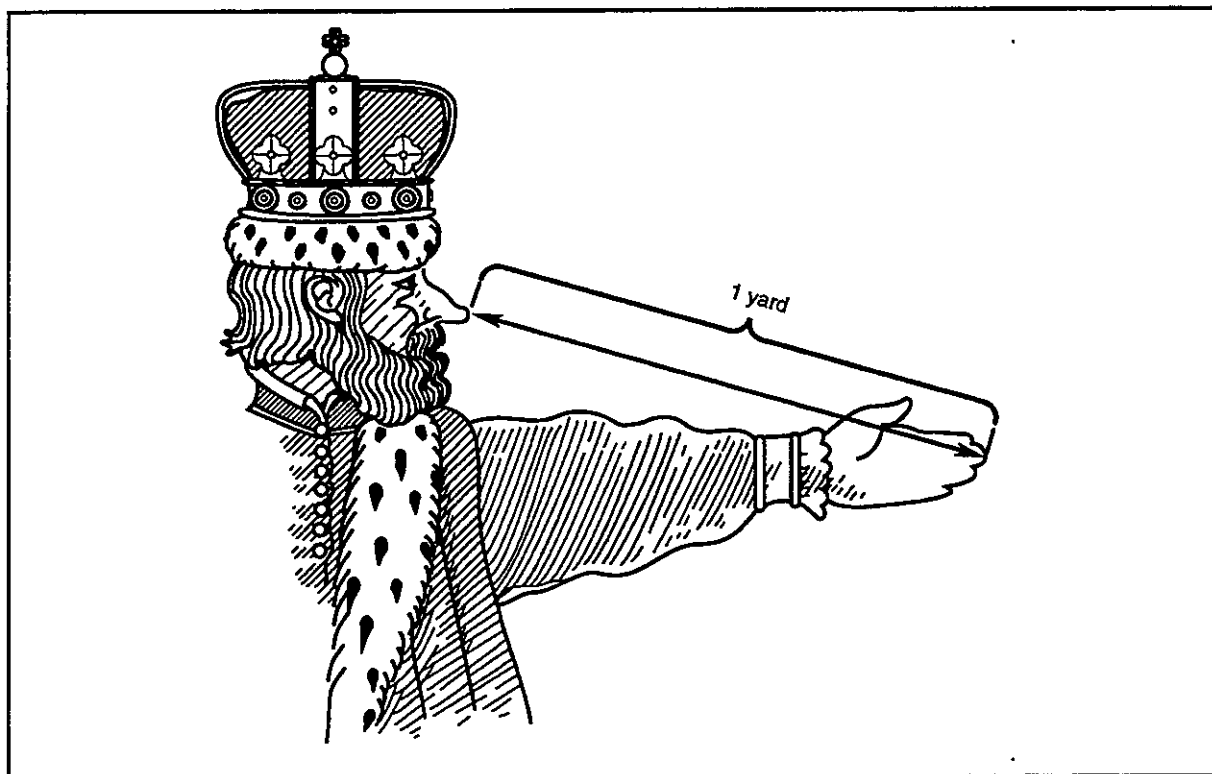


Figure 4. Yard definition.

Converting units of the inch-pound system of measurement is very time consuming. Indeed, virtually no one knows that 1 mile equals 5,280 feet, or 1,760 yards, or 63,360 inches. In the metric system, everybody knows that a mile equals 10 kilometers, or 10,000 meters, or 1,000,000 centimeters. Dealing with 10's, 100's and 1,000's makes a lot of sense, is much easier, and is less time consuming.

Figure 5 highlights a study by Dr. E. James Tew, Jr., Texas Instruments, Inc., Dallas, TX. In the study he conducted, a group of adults, engaged in training for high-tech jobs, were given tests for problem solving using inch-pound units and metric (SI) units. Results of the tests indicated that 40 percent less time was needed to solve problems using metric units.

C. The Metric System

Before the development of the metric system, every nation used measurement units that had grown from local customs. During the 1600's, some countries recognized the need for a single, accurate, worldwide measurement system. Several Frenchmen proposed new ideas, e.g., a decimal measurement system, a pendulum that swung once per second as a standard unit of length. In 1790, the National Assembly of France requested the French Academy of Sciences to develop a standard system of weights

Dr. E. James Tew, Jr., Manager, Quality Assurance Operations, Texas Instruments, Inc., Dallas TX, presented a report of a study he conducted in which a group of adults engaged in training for high technology jobs were given tests for problem solving using inch-pound and SI units. Results of these tests indicated that 40.5 percent less time was needed to solve problems in metric than when inch-pound units were used. Tew wonders why we can't complete metrication, a process which is so simple and which would aid us so much in technological education and industry applications.

Telephone: 214-480-2234

1987 Nov.-Dec. USMA Newsletter

Figure 5. Inch-pound versus SI units.

and measures. Also in 1790, Thomas Jefferson, then U.S. Secretary of State, recommended that the U.S. use a decimal system of measurement. Congress rejected the idea, but left the monetary system in tact.

The International System of Units evolved from the meter and the kilogram, which were created by members of the Paris Academy of Sciences and adopted by the National Assembly of France in 1795. In 1875, the "Treaty of the Meter" was signed by the U.S. and 16 other countries at the close of an international conference.

Figure 6 shows the organizational structure of the international committee. The main groups are:

- International Bureau of Weights and Measures,
- International Committee on Weights and Measures (CIPM),
- International General Conference on Weights and Measures (CGPM).

These organizations were established to update the metric system as necessary. The meter/kilogram standards are those adopted at the CGPM, and they have been distributed to all countries that signed the "Treaty of the Meter."

In 1960, by international agreement, the 11th General Conference (CGPM) established the "Modernized Metric System," the new system of measure, called the International System of Units, officially abbreviated "SI" in all languages. "SI" is standardized for international use through the International Organization for Standardization (ISO). "SI" is based on seven base units: length, mass, time, electric current, temperature, amount of substance, and luminous intensity. There are also two supplementary units: plane angle and solid angle. The base units for time, electric current, amount of substance, and luminous intensity are the same in both the inch-pound and metric systems. Figure 7 summarizes these CGPM developments. Further updates and improvements to "SI" were made over the years during the general conferences.

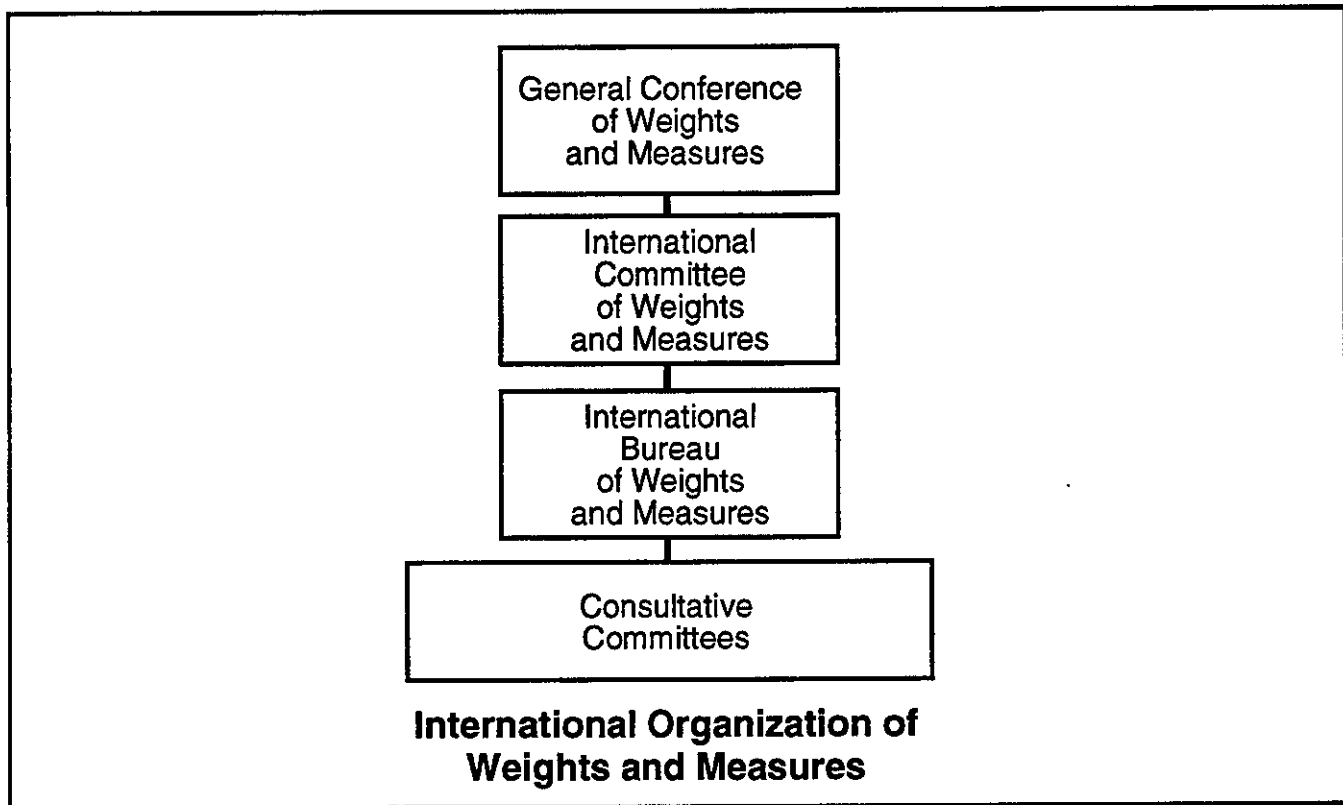


Figure 6. International organization structure.

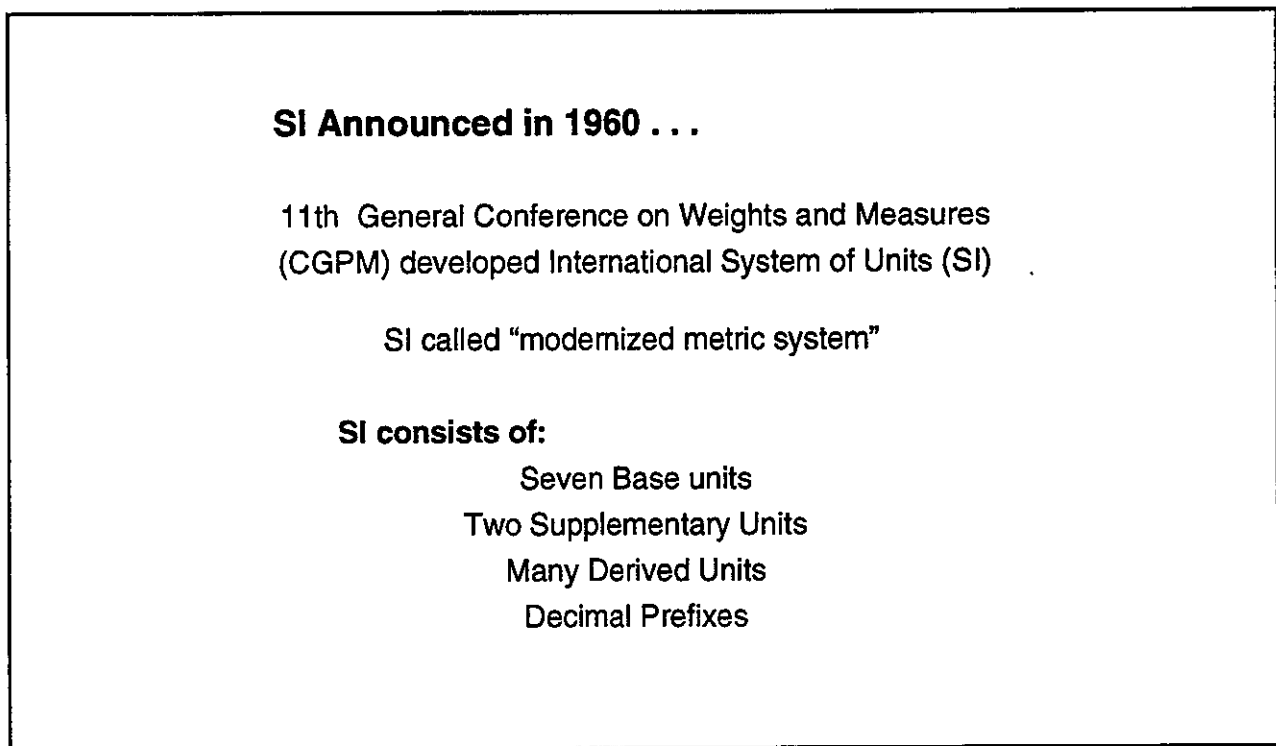


Figure 7. The modern metric system.

The metric system is a "base-10" or "decimal" system. The larger or smaller versions of each unit are created by multiplying or dividing the base unit by 10 and its powers. This feature provides a great convenience to users of SI by eliminating the need for dividing by 16 (to convert ounces to pounds) or by 12 (to convert inches to feet). An example of how easy it is to convert 4,653.5 millimeters to centimeters, decimeters, or meters is that by dividing the millimeters by 10 we obtain centimeters and by repeating we obtain decimeters and meters. Whenever we divide, we shift the decimal one space to the left (mm to cm to dm to m). Thus, we have 4.6535 meters.

The committee assigned the name "meter" to the unit of length. Originally, the physical standard representing the meter prototype was to be constructed so that it would be one ten-millionth of the distance from the North Pole to the Equator along the meridian of the Earth running near Dunkirk in France and Barcelona in Spain. Today, the meter is defined as the length of the path traveled by light in a vacuum during a time interval of $1/299\,792\,458$ of a second.

The kilogram (fig. 8) is the only SI base unit defined by an artifact, a cylinder of platinum-iridium alloy. The prototype kilogram is kept by the International Bureau of Weights and Measures near Paris, France. Each CGPM member country received a duplicate of the prototype, which, in the United States, is kept by the National Institute of Standards and Technology (NIST). The unit of mass is called "gram" ($1/1,000$ kg). One cubic centimeter of water at its temperature of maximum density (4°C) has a mass of 1 gram. One cubic decimeter (1 liter) of water at 4°C has a mass of 1 kg.

Most scientists and other professionals all over the world use only SI units in their research, development, designs, and projects, except in the U.S. It should be emphasized that the changeover to metric in the U.S. means a changeover to SI. This is by decree of all professional and educational societies that took an active part in the SI decision making.

Perhaps the slow progress of metrification in the U.S. is based on a general public feeling of ignorance about SI, and rather than admitting ignorance or suffer embarrassment, we begin to defend the old-fashioned measurement system that we know, even though we know that the inch-pound system has been proven inferior to the metric system.

III. GLOBAL CONVERSION EXPERIENCE

A. General

Other nations began to convert to the metric system after 1840 when the French people were first required to use it. Ten years later, four more countries had accepted the new units of measure, and by 1900, 35 nations had adopted the metric system. Today the world is metric! The United States is the only industrial nation in the world which insists on hanging on to the archaic "inch-pound" system (the "English" or "Customary" system), a system which has been abandoned even by its originators.

B. British Experience

The nation that developed the "Imperial" system of weights and measures — the inches, ounces, and quarts, familiar throughout the English speaking world — announced its decision to abandon the system in favor of the decimal scheme and to embark on a 10-year metric conversion program (1965 to 1975). Britain's decision to adopt the metric system was in recognition of a number of circumstances:

the speed of the spread of the metric system; changes in the country's export position; close links between science, technology and industry; and most directly, pressure from British industry. There was a certain amount of nostalgia in the adherence to the Imperial system, and when a member of the Parliament raised the question of going metric, the answer was, "do you expect the British workman to go into a public house and ask for 0.56825 liter of beer?" In 1965, most of the commonwealth nations and former British colonies had decided to go metric, the U.S.S.R. was adopting SI, and China used the metric system. In England, everybody was to go metric: the construction industry, engineering, transportation, road system, schools, agriculture, land survey, extraction industries, professions, wholesale and retail trade, and ultimately the kitchen.

The metrication board in England commissioned handbooks, manuals, and standards to be developed by British industry, research associations, and technical societies. "Metrication in the Machine Shop" is such a manual which was developed to facilitate conversion to the metric system. One question that every machine shop had was, "What happens to machinery used to manufacture inch-pound parts?" This question is answered in section B, "Machine Shop Conversion," page 31. The text draws from the British experience and their conversion manual.

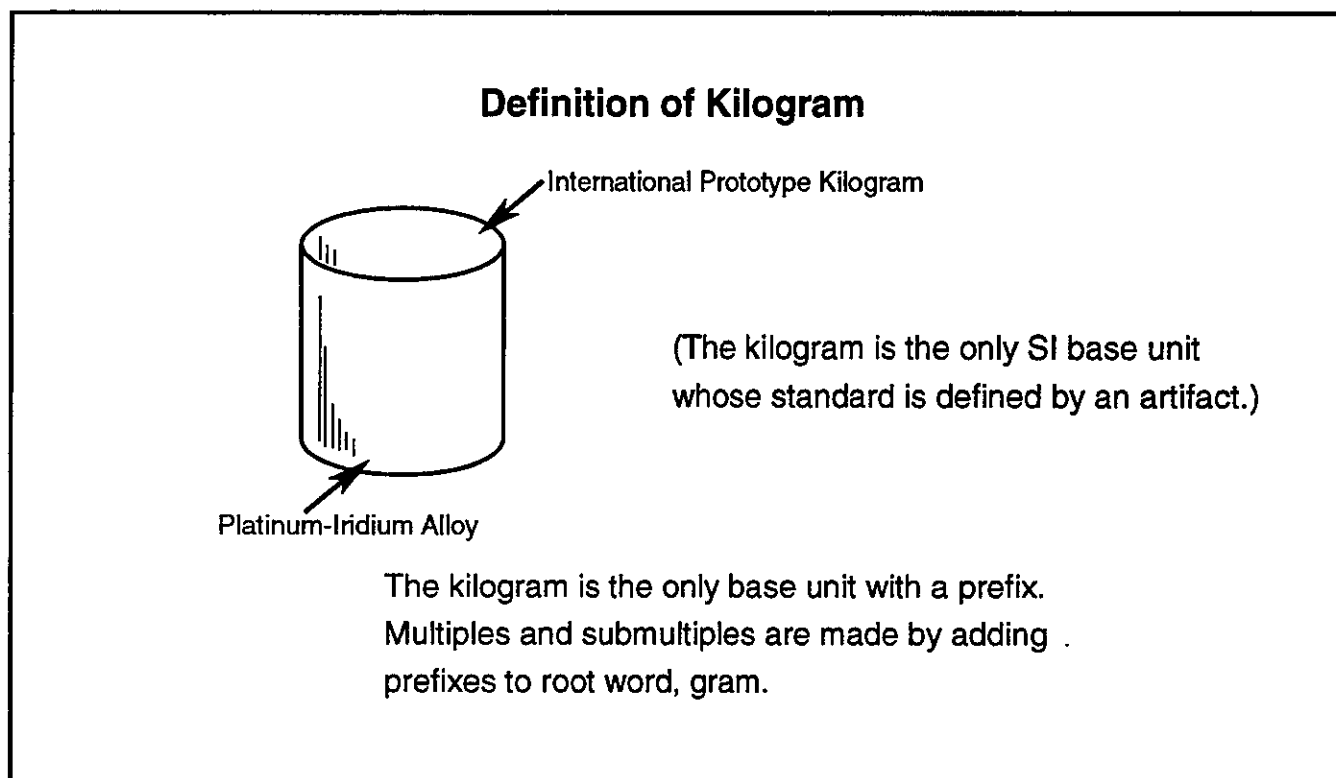


Figure 8. Definition of kilogram.

International trade data are now metric. This forces nonmetric U.S. exporters to convert their products, product descriptions, and documents to metric. A recent experience may seem a bit extreme: when General Electric was exporting kitchen appliances to Saudi Arabia, they left a 6-foot cord installed instead of a 2-meter cord. The customer did not accept the appliances based on nonconformance. Not only will metric-dimensioned products be required, but in some areas like the European Community (EC), a comprehensive framework for product certification, product standards, and product testing (the ISO 9000 series of quality specifications) is required.

C. Australian Experience

In 1970, Australia began a scheduled 10-year conversion to the metric system. The conversion of industry was central to conversion of the country as a whole. By creating an environment of metric goods and services and by regular use of metric in the workplace, Australians were able to learn to use metrics (SI) in a natural way and at their own speed, without fear of having to go back to school to learn what they already knew well enough to do their work. Mr. Kevin Wilks served as a member of the Australian Metric Conversion Boards during the time it was active. He recommends a seven-step approach for U.S. companies to change over to SI. The Federal Government has a mandate to use the metric system. The law does not require industry to change, but companies that delay conversion will lose valuable time and future economic benefits in a metric world.

1. *The Management Decision.* The first step is for top management to authorize the metrication project to begin. A senior executive should be appointed as metrication chief or chairman of the metrication planning committee. It is most important that top management demonstrate its commitment to the project by giving high status to the position of metrication chief. Most metrication tasks have a low "interest index" and high "nuisance value" to the person trying to do the job. If the planning committee has the full support of management, the work will be done a good deal more effectively than if management is publicly unenthusiastic.

2. *Draft the Metrication Plan.* Many guidelines or conversion checklists are available from the Department of Commerce (Metrication Office), professional societies, or companies that are already metric. Use the Government-approved document ASTM E-380, "SI Metric Guide," as the basis for company metric usage (available from ASTM, 1916 Race St., Philadelphia, PA 19103). There are two major "metric" organizations that also have planning documents available:

- a. The U.S. Metric Association, Inc. (founded in 1916), 10245 Andasol Ave., Northridge, CA 91325
- b. The American National Metric Council (established in 1973), 4330 East West Highway, Suite 1117, Bethesda, MD 20814-4408.

Information from these sources will save a lot of time when preparing the first metrication plan.

3. *Metrication of Engineering Standards.* A large number of U.S. and company standards have been converted to metric. Approximately 10,000 ISO standards are also available in the English language. It is important that a company seek advice on how to convert company standards. Most important is that existing standards be used if they can be applied to local conditions such as machine shops and processes.

4. *Legislation, Regulations, and Codes.* Like standards, there are a great number of commercial products and processes bound by legislation of one sort or another. These include building regulations and codes of practice, highway and transportation codes, weights and measures, industrial labor agreement, and many more.

In Australia, a nationwide agreement between state building authorities on a minimum ceiling height of 2,400 mm to replace 8 ft or 2,438 mm was the most important single factor in developing a new uniform building code. In the U.S., we are not changing our codes overnight, but we are constructing "metric" buildings from metric designs and available materials. Eventually, design codes, regulations, etc., will be all metric.

5. *Raw Materials and Components.* No firm conversion date can be set by a company until it knows that essential raw materials and components will be available in appropriate metric sizes. Early requests to suppliers for metric materials with constant followup will be essential if deadlines are to be met. Obviously, allowances must be made for long lead time items, and a large amount of mutual tolerance will be essential. One major problem in obtaining metric supplies is that your requirements for metric products may be a small percentage of a supply company's market and they prefer not to accept your order. If this happens, you may have to live, for a while, with a mixture of metric and nonmetric materials and components. This will most certainly happen with fasteners and sheet metal sizes. This approach is very acceptable in early conversion efforts.

6. *Marketing Metric Products.* Without doubt, the most difficult task in the whole metric change-over is to maintain your market share and retain consumer loyalty in the face of unfair competition from companies in the same industry which refuse to convert in order to take advantage of opportunities presented. The Australian experience was that people preferred not to buy metric goods and services as long as well established nonmetric products were still available and suitable for use. The only solution to this problem was government protection.

a. Standards: Where goods or services are produced to a standard or legal code, metric conversion cannot be announced until it is known that codes or standards are converted. More importantly, once the standard or code is published in metric, the consumer has no option but to accept it.

b. Collusion: Under the trade practices legislation in Australia and the antitrust laws in the U.S., there are strict limitations on the amount of collusion permitted between companies. In Australia there was no collusion because companies in the same industry were invited to meet with the Metric Conversion Board to develop industry conversion plans. In the U.S., it seems unlikely that private meetings between companies in the same industry, even for the purposes of metrication planning, would be exempt from antitrust laws. Therefore, such meetings should be called by Government officials, and agreements should be made a matter of public record. By an interchange of individual company programs, by publication in appropriate trade journals, professional society documents and meetings, general media releases, inter-company circulars, and by the metric program office, NIST, D.O.C., there would be no problems with the antitrust law.

c. Positive marketing techniques: Companies which are negative, defensive, apologetic, or pessimistic about their ability to sell metric products will, almost certainly, lose sales and market share. Three suggestions are given:

1. Incorporate new features in the "metricated" product.
2. Avoid complicated numbers in descriptions:
 - Use rounded off numbers to an appropriate order of accuracy
 - As name or size, e.g., lumber use "2×10" not "47×245"
 - When using "ball park" figures, e.g.,
 - "missed by an inch" use "missed by a centimeter"
 - "about a mile away" use "about a kilometer away"
 - "a 200 MPH gale" use a 300 km/h gale."

3. Publish aids for using metric. It is not easy to change the measurement habits of a lifetime, and it is obnoxious to tell people it is.

7. *Implementation.* When your company is ready for implementation, your metrication coordinator should have completed all the necessary analyses, initiated changes in standards, gotten agreements from suppliers, worked out effective marketing strategies, established stock rooms, located distributors, and done quite a lot of work. The feasibility of your metric program has been established and management directs you to implement the program.

In the plant, existing equipment has been modified for working in metric. Many machines, gauges, meters, and scales have new decals or dials, or are simply overmarked. Companies should not automatically scrap functional nonmetric equipment, but should modify it, where possible, for working in metric. With minimum inconvenience, much of the nonmetric equipment can be retained and replaced on a normal obsolescence program.

The final step before Metric Day (M-Day) includes employee training. Training should be restricted to whatever is necessary for employees to be able to perform assigned tasks in metric. To ensure that training is quickly followed by implementation, the training sessions should begin no more than 3 months before "M-Day." Everything must be planned to the last minute detail.

A comparison that I like to make is the planning and execution of the changeover from driving on the left side to the right side of the roads in Sweden. The changeover was made overnight, and in the morning, the Swedes woke up to driving on the right side of the road. An intensive advertising campaign in the news media, distribution of flyers and pamphlets, and mailings had prepared the public (which had mixed emotions about the changeover) to drive on the right-hand side of the road. The amazing point is that the Swedes changed their habits without any major accidents. I believe that the U.S. must sponsor a similar approach to metrication, "just do it."

D. Canadian Experience

Canada has adopted the metric system. "The White Paper on Metric Conversion in Canada" was tabled in the House of Commons by the Minister of Industry, Trade, and Commerce in 1970. One year later, Canada's Weight and Measures Act (1971) proclaimed that "all units of measurements used in Canada shall be determined on the basis of the international system of units established by the General Conference of Weights and Measures." With 98 percent of the world population using a variety of metric units, this decision was of vital importance to Canada's foreign trade and advantageous for international exchanges of all kinds.

In Canada, the Federal Government established "The Metric Commission Canada" to help plan the Canadian metrication. Ten steering committees were formed, each responsible for coordinating a group of economic sectors with related interests. Representatives from more than 700 national, industrial, consumer, service, labor, trade, agricultural, professional, and educational firms and associations were asked to support these sector committees to investigate and plan for metric conversion and to suggest a schedule of implementation most suitable to their sectors.

In 1975, Canada began a gradual changeover to the metric system. The decision was made following Britain's and other commonwealth countries' conversion and based on the understanding that the U.S. would also soon change to the metric system. Today Canada is metric! The U.S. is not!

The North American Free Trade Act has opened the door to metric markets north and south of our borders. We now have metric products flowing in both directions across these borders. Our domestic market shows no reluctance to accept metric products whether "made in USA" or imported. Therefore, U.S. firms can likely satisfy both the domestic and export markets with one product line—the metric product line. There will be no need to maintain dual production lines, no need to work with two sets of standards, and no need to maintain two sets of inventories and spare parts. In the beginning of the Canadian metric program, consumers were afraid that they would get less for their money, manufacturers were afraid they would spend on conversion with no return, and suppliers were fearful of competition from overseas. Teachers worried about teaching metric, and the elderly said they would never learn metric.

Canadians found that SI is similar to but different from the old metric systems. SI includes familiar metric units such as meter and kilogram. However, there are a number of changes from the former metric systems, e.g., the centigrade temperature scale is called the Celsius scale. This is a change in name only, so that 20 °C, formerly read as "twenty degrees centigrade" is read as "twenty degrees Celsius" in SI. This kind of change was not difficult for the Canadians familiar with older metric systems. Other changes, especially derived units which are of a more specialized nature, took a longer time to learn.

IV. U.S. CONVERSION EXPERIENCE

A. General

U.S. conversion to the metric system has been an issue almost since the creation of our nation. Many Americans have had some contact with the metric system. Many have worked in or toured metric countries in peace and war, and others were born in and lived a good part of their lives in metric countries before coming to the U.S. For many years, the idea of metrication (metric conversion) in the U.S. has faced many problems. It has been discussed in Congress for the past 200 years, at somewhat regular intervals. The Department of Commerce issued a 300-page history of the U.S. metrication and its controversies. It identified five phases of our conversion efforts through 1971.

1. *The Period of Consolidation (1786–1866)*. During this period, emphasis was placed on uniformity of monetary units and weights and measures. The diversity of units stemmed from the settlers' ties with their old homelands and their desire to use familiar units. The adoption of the decimal system for coins shows how close we Americans were to a simple system. This period culminated in 1866 when Congress legalized the use of the metric system.

2. *The Educational Movement (1866–1899)*. During this era, the primary goal of supporters of the metric system was to secure widespread acceptance and voluntary use by educating people about its advantages. Further legislation could not be passed until the people as a whole were ready for it.

3. *Government Adoption Movement (1890–1914)*. In this era, supporters adhered to a strategy that called for a rapid adoption by the Government, followed by a general transition by the rest of the country. It was assumed that the best way to acquaint the greatest number of people with the system was by adopting metrics for all Government work.

4. *The Propaganda Period (1914–1933)*. This era saw the emergence of forces strongly promoting and strongly opposing metric conversion.

5. *The Study Phase (1934–1968)*. This period culminated in 1968 with legislation directing the Secretary of Commerce to conduct a comprehensive investigation of metric conversion. This study is documented in "A Metric America: A Decision Whose Time Has Come." It was published in 1971, in 12 volumes.

It seems that we are still in a "study phase" instead of a "just-do-it phase."

When the need to go metric becomes an issue, it seems that the first thing we decide to do is to complete a study to determine which measurement system should be used, the inch-pound or the metric system. We have a sufficient number of studies to know that all we need to say is, "just do it!" Cost impacts are often quoted as problems of conversion to the metric system. Actual cases of metrication indicate the opposite—companies are making profits by their decision to metricate. Going metric helped streamline operations at International Harvester and John Deere and Co., the manufacturers of farm and industrial equipment. With metrication, John Deere reduced the number of different screw sizes from about 70 to 15. General Motors Corp. projected that their cost increase to go metric would be about 6 percent and were extremely surprised to find that the changeover was less than 1 percent of the projected cost. Other areas where outstanding metric progress is being made include the U.S. construction industry and the Federal Highway Department. In the period since the issuance of the commerce study, we have many successful conversion stories as well as failures encountered with metrication projects. Some of these will be discussed later.

The Metric Conversion Act, enacted by Congress in December 1975, did not indicate a preference for one system over the other. The act established a metric board which could not advocate metrication but could offer assistance when and if an industry chose to convert and requested help. Most consumer-oriented U.S. companies did not change their products. The voluntary conversion of 1975 was perceived by them as a possible annoyance to their customers. The board did not push metrication nor unanimity, and soon the metric board discontinued its efforts.

Congress understood the need for adoption of the metric system in trade and commerce and expressed their rationale in the 1988 amendments to the Metric Conversion Act of 1975. The "Omnibus Trade and Competitive Act of 1988" requires Federal agencies to use the metric system in measurement-sensitive programs and functions relating to trade, industry, and commerce. Executive order No. 12770 of July 25, 1991, directs Federal agencies to develop metric transition plans, to cooperate on mutual transition issues, and to submit progress reports. An annual report from the Secretary of Commerce to the President must include an assessment of progress toward achieving "the national goal of establishing the metric system as the preferred system of weights and measures for United States Trade and Commerce."

B. Education

Our educational institutions began teaching metrics in the 1970's, but the lessons were not well organized nor well received. A few students used metrication for extra credits and did very well in science projects. But no one seemed to understand why the big push for metrics because there seemed to be no requirement for metrics. In the general job market, everyone seemed to think that it was just one of those exercises that had nothing to do with the real world. Few teachers continued metrication programs. General public apathy and limited experience in teaching the metric system lead to the slow down.

Research has shown that one reason people have so much difficulty in math in the U.S. is the cumbersome inch-pound system. The Education Bill that Congress passed in the spring of 1994 has

several references to the metric system, and perhaps metrication will do better this time. The law says that we must go metric by 1995 or show reason for late implementation.

For practicing engineers, there are workshops, video cassettes, and other training materials available from sources like the U.S. Metric Association and the American National Metric Council.

The Department of Education has a key role to play in the U.S. metric conversion plan. Early in 1994, the Government's Metrication Operating Committee (MOC) designated education as "the lead agency to seek out ways to increase understanding of the metric system through educational information and guidance." Education is still progressing at a slow pace, and we need to push for "knowledge of the metric system" as a national educational goal.

C. Construction

The construction industry is another success story. "Federal construction represents a large part of the nation's construction industry. Federal appropriation for construction, including grants and aid to the states, now total over \$50 billion" (from "Metric in Construction" January 1994 newsletter). About \$20 billion of this total is for metric design and construction.

NASA has a very active metric construction program. In recent years, the construction of new facilities, additions to existing facilities, and maintenance has been an area where headquarters has invested funding for metrication. Every major center has some kind of metric facility program in progress.

Figure 9 lists details of the MSFC metric pilot project, the Aerophysics building No. 4732. The \$700,000 project adds approximately 650 square meters of office space. The project is a combination of a second floor addition to the existing first floor and construction of a new two-story section. Figure 10 shows the site plan, and figures 11 and 12 show how the metric design has been tied in with the existing inch-pound building. The MSFC design approach for inch-pound facilities was used for the metric pilot project with the addition of the minimal metric requirements presented in figure 13.

MSFC Metric Pilot Project

- Addition to Aerophysics Building 4732 selected as pilot project in May 1992
- Addition will add approximately 650 square meters of office space for ED lab
- Project is combination of second floor addition to existing first floor and construction of a new two-story section
- Design started May 1993
- Design completed November 1993

Figure 9. MSFC metric pilot project.

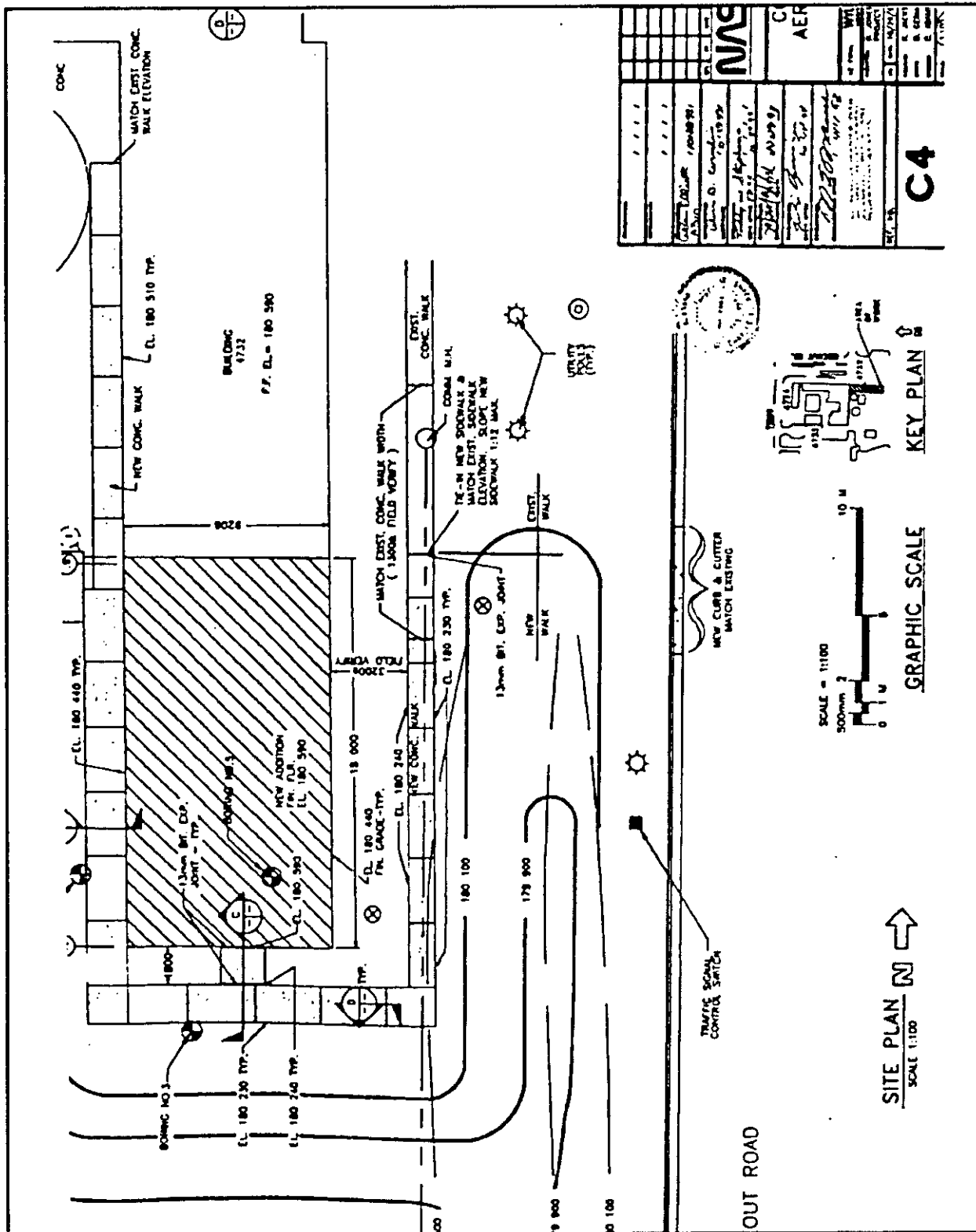


Figure 10. Site plan.

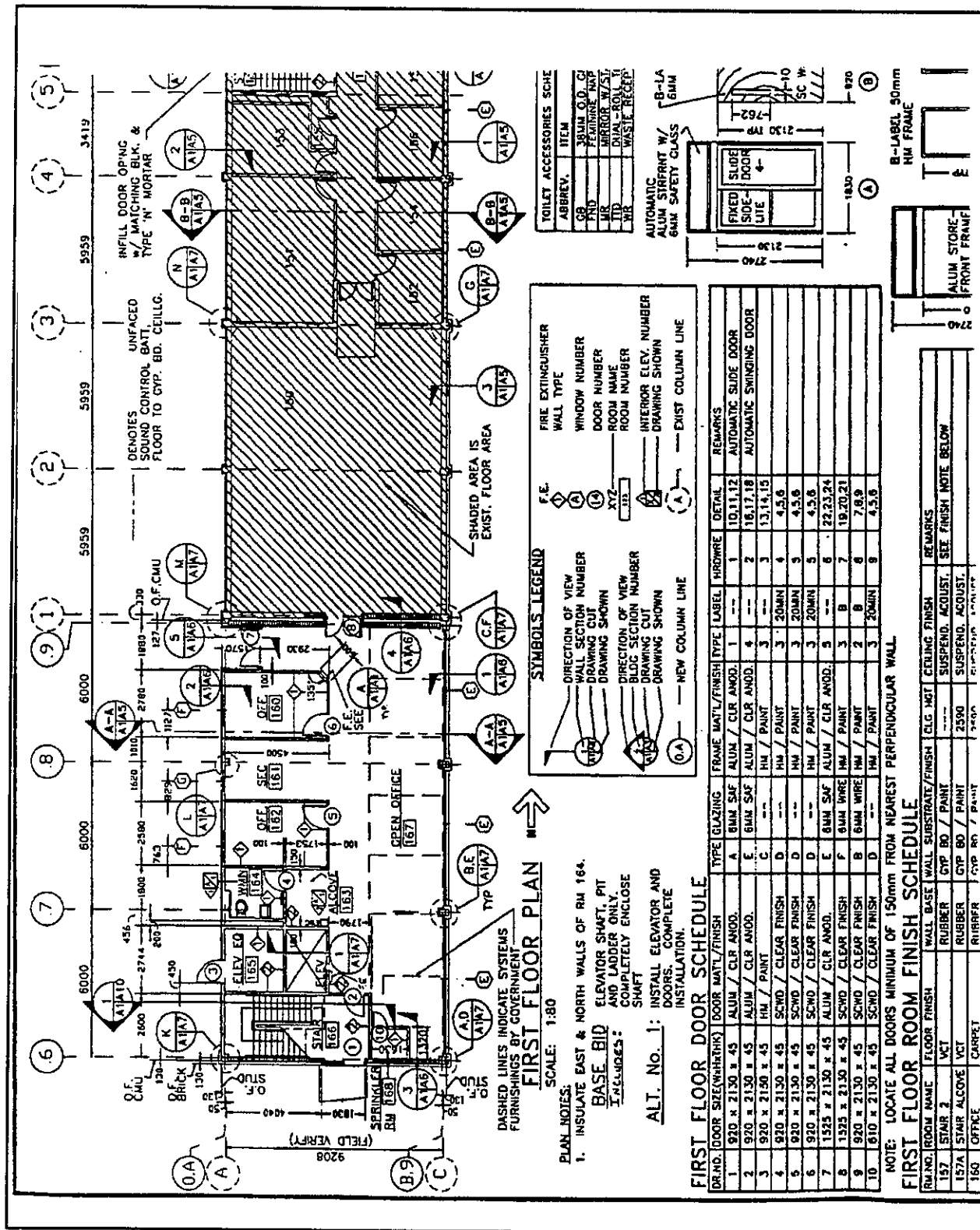


Figure 11. Floor plan.

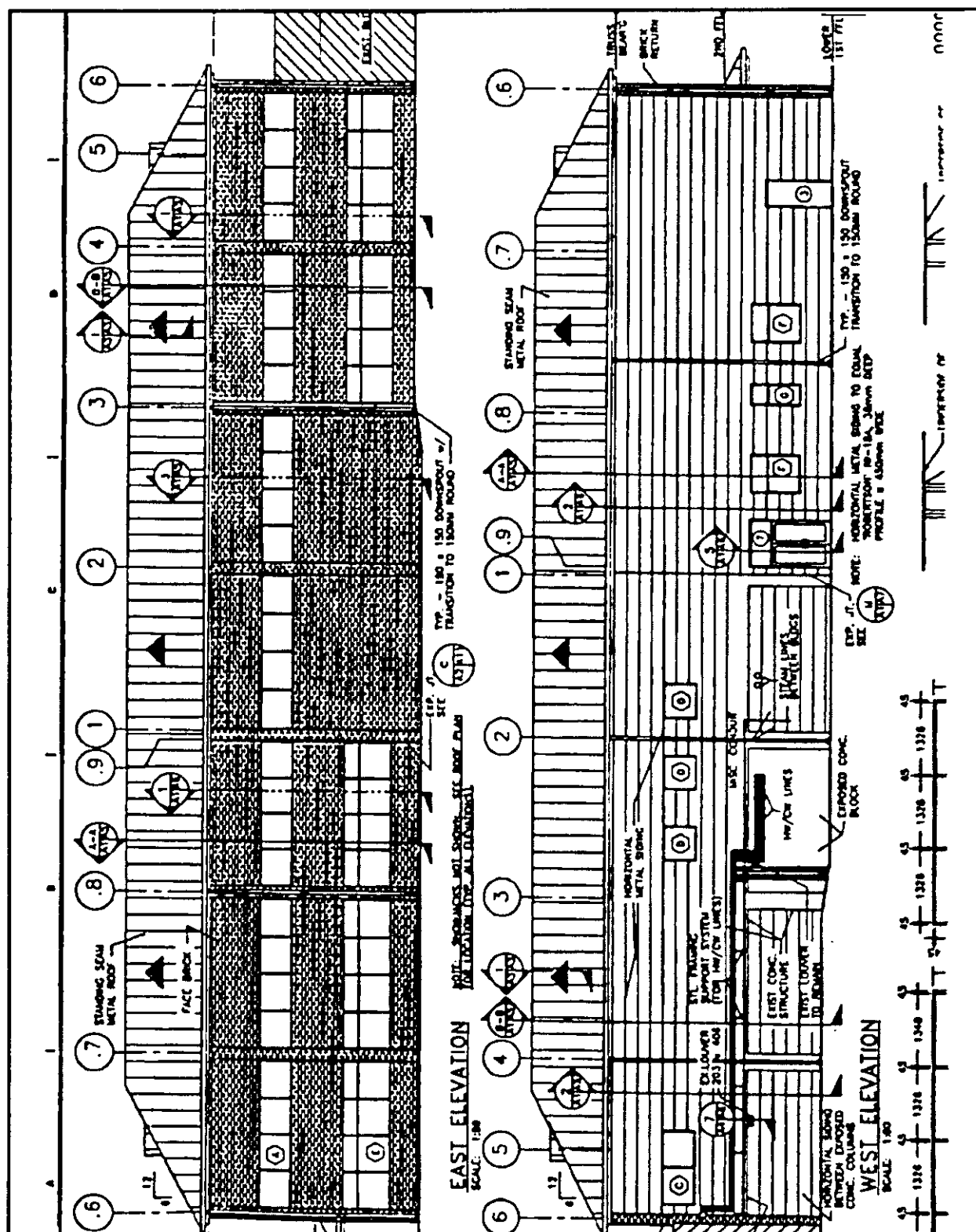


Figure 12. Elevation.

Design Approach for Pilot Metric Project

- Same as nonmetric but add requirement for A-E design in accordance with GSA Metric Design Guide
- MSFC to determine if project will include hard metric grid and products
 - Research indicates cost increase for hard metric
 - No \$\$\$\$ for metric in budget
 - Drawings, specs., calculations, and cost estimate in metric units
 - Technical data on materials to be described in metric
- Hard metric NOT used because of \$\$\$\$\$\$.

Figure 13. Design approach.

The building industry is moving rapidly toward "hard metrics," i.e., designs and products are made using metric dimensions. However, allowances are made to use existing hardware with inch-pound dimensions and converting to the closest metric numeral. Initially there is no need to change block, brick, and gypsum board sizes. Architects need only specify a wall size and door and window dimensions and placements; the builder will do the rest. Eventually the marketplace will catch up and decide on board and block sizes. Structural, floor, and concrete strength should use rounded off numbers, e.g., "4,000 psi concrete" should be called "30 mPa concrete" (do not use the exact conversion, 27.56 mPa). A little known fact is that the glass industry has been metric for many years, e.g., No. 6 glass is 6 mm thick.

D. Transportation

The Department of Transportation (DOT) has decided to include metric requirements for Federally funding assisted highway construction. DOT provides about \$18 billion in assistance to state agencies for highway construction. Beginning September 30, 1996, state agencies receiving Federal funds will be required to use the metric system in the measurement-sensitive aspects of their plans for road construction. Measurement-sensitive areas include depth of pavement, length of roadway, width of lanes, quantities of testing of materials, and other elements.

The Alabama Department of Transportation is cooperating with the U.S. Department of Commerce and the Federal Highway Administration to convert to "SI" by October 1, 1995. The metric committee of the Alabama Department has produced a booklet, "Moving to Metric." Copies are available from Mr. Randall A. Estes, P.E., Metric Boulevard, Montgomery, AL 36130-3050. All highway users will eventually be affected by the "new" metric signs (some new, others will be the old signs with metric overlays). Mr. Estes emphasizes that metric is the world standard for measure, "there is no 'if' in

metrication!" The Alabama Department of Transportation target date for complete conversion to the metric system is October 1, 1995. Figure 14 lists other target dates, note the Federal Highway Administration (FHWA) approval of October 31, 1994, and that some reporting in metric is required in FY95. The 1-year advance assures ALDOT to complete conversion prior to the FHWA target date of September 30, 1996. Figures 15 and 16 show the Alabama philosophy of conversion, the Highway Director's commitment, and the task for the metric conversion committee. "Public awareness" and "converting dimensions" are included as appendices "B" and "C."

Program Elements/Activities	Target Date
I. Develop FHWA metric conversion plan.	Approved October 31, 1994
II. Initiate revision of pertinent laws and regulations that serve as barriers to metric conversion.	1991
III. Conversion of FHWA manuals, documents, and publications.	1994
IV. Data collection and reporting.	1995
V. Direct federal and federal-aid construction contracts.	September 30, 1996

Figure 14. Conversion target dates.

Philosophy of Conversion

- Expect resistance—it's natural
 - Start now—it's already late
 - The status quo is comfortable
 - No change is best for the short-term
- Project a positive image about metric
 - You MUST talk metric
 - You MUST plan metric
 - You MUST push metric
- Involve everyone
 - Do not leave anyone out
 - Hold meetings with your personnel
 - Call in "outside" experts for advice
- Avoid dual units like the plague
 - Do not think about it
 - Do not plan it
 - Do not do it
- Aim for long-term benefits
 - Look at October 1, 1994 deadline and work back
 - Do not consider cost/benefit ratios
 - Do not consider value engineering

Figure 15. Philosophy of conversion.

The Structure of Metric Conversion

- Department support
 - Highway Director's commitment
- Metric Coordinator
 - Randal A. Estes, P.E.
(Phone: 205-242-6277)
- Metric Conversion Committee
 - Metric Coordinator
 - Administrative Section Representative
 - Bureau Representative (1 per bureau)
 - Division Representative (1 per division)
 - F.H.W.A. Representative
 - Others as deemed necessary
- Developing the plan
 - Identify general area of concern
 - Identify all areas of change
 - Schedule activities
 - Set target dates
 - Establish flow charts
 - Plot and/or define complex events

Figure 16. Structure of conversion.

Metricating the DOT will not be as difficult nor as costly as might be expected. Other nations did not find it to be a big deal when they converted to "SI." There is no deadline for a hard metric detailed design, only the overall documents need be "hard metric" to obtain Federal approval. Each state will submit their metric program/plan to the Federal Highway Administration (FHWA) for approval. These plans must show that the states are making "good faith" effort toward metric conversion. In order to minimize the impact on private industry, consideration will be given to the use of "soft" converted hardware. For example, initial prestressed girder sections will likely be fabricated to existing English dimensions, converted to the nearest millimeter. Pipe sizes will remain the same; simply respecified in metric dimensions. It is anticipated that metric surveys will soon be completed, and that the "hard metric" design process will begin soon.

V. LOCAL EXPERIENCE

A. Government

NASA, Marshall Space Flight Center (MSFC), and their forerunners (Guided Missile Development Division and ABMA) had close ties to the metric system, partly because they employed many engineers who had been educated in "metric" countries such as Austria, Germany, and Sweden. They preferred the metric system because it saves computation time, is simple and reliable, and because some of the rocket designs and parts came from Europe (V-1's and V-2's).

A specific item that indicates the situation is the computation of missile trajectories at MSFC which were done using meters, kilometers, and kilograms. The results were converted and compared with computations using customary units (feet, nautical miles, and pounds). Arguments between proponents of the two systems became more intense every year. Finally, NASA Headquarters called for a conference at the Langley Research Center on July 15, 1964. The conference, "A Study of the Preferred System of Measurement for NASA Activities," decided in favor of adopting the metric system and published a document "A Plan for an Orderly Transition to SI." Unfortunately this plan was never implemented, perhaps due to normal human resistance to change, despite the numerous and obvious advantages that the report stressed.

In 1968, Congress directed the Department of Commerce, National Bureau of Standards (NBS), to study the advantages of going metric. It became the most extensive study NBS had ever made. After 3 years, the conclusion was that metrication was a necessity. The recommendation was that the U.S. should implement metrics.

NASA and most of its centers, including MSFC, had considerable positive inputs to the NBS report. Practically all Federal agencies as well as professional societies had forwarded inputs. Thinking that metrication was "just around the corner" and that NASA, a prime research/scientific organization, could and should play a leading role, the Center initiated metrication efforts like:

1. Metric exhibits
2. Metric handouts
3. Metric posters
4. Metric traffic signs
5. Metric bibliography
6. National Metric Week observance
7. In-house metric pilot projects
8. Contractor metric pilot projects
9. Engineering standards conversion
10. Design courses at local universities
11. Films and cassettes at Training Branch
12. Metric references at Redstone Scientific Information Center (RSIC)
13. Contacts with state and local governments
14. Contacts with Australia, England, Canada, et al.

15. Professional societies' metric programs

16. MSFC contractor metric interfaces.

NASA is a major procurement agency and one of the key agencies with global operations. Many countries contribute directly or indirectly to flight missions, research and development of experiments, payloads, and satellites. One example is the remote manipulator system developed by Canada for the shuttle orbiter. Other countries support and operate ground stations and equipment to ensure mission success. This requires international cooperation in research, development, and operation. Since all participating countries are using the metric system, the U.S. metric conversion is a necessity for maximum efficiency and reliability.

At MSFC, we have initiated several pilot programs. Each of these programs was very successful up to the point when we were ready to proceed into full-scale development, at which time we had to postpone further development due to lack of national conversion activities.

The RSIC has established a special metric section where NASA, DOD, universities and local industry may obtain the latest information and news about metrics. Most of the historical metric data generated locally can be found here. Practically all world-wide metric standards are available. Naturally metric periodicals, reports, and reference books have been cataloged and are available on ROM disks.

The Commanche helicopter is a DOD metric success story. Its propulsion system is virtually 100-percent metric. One noteworthy advantage is the tool kit needed to overhaul the engine. It was reduced from 409 tools to only 6. This is an extremely important event for metrication. At MSFC, we stress that metrication represents a unique opportunity to save time and money by using fewer tools, fewer types of fasteners, and fewer varieties of parts; we call this "type-reduction," i.e., by using scientifically spaced sizes, limiting thickness, and varieties of parts we will save money. Practically all the products of industry have to be manufactured in a range of sizes, outputs, or ratings. This can be accomplished by choosing a series of sizes that minimizes choices and inventories yet is sufficient for independent design and development.

In 1877, Col. Charles Renard pointed out that, in a vast majority of cases, experience showed that the range of values most likely to meet all needs was that in which a geometric progression was followed. He was able to reduce the number of different dimensions of rope for military balloons from 425 to 17, with the aid of a geometric series. In today's world, it has become increasingly important from a cost standpoint to limit the number of standard parts, material, and components used in products. A preferred series of numbers can provide the tool to achieve this goal. The internationally agreed-to series is known as "Renard series" or the "Renard system" of preferred numbers as shown in figure 18. The preferred number series is independent of the measuring system used, but it has played an important role in the countries that have converted from the inch-pound system to "SI." Think type reduction when you think metric! In figure 17, the preferred numbers in R5, R10, R20, R40, and R80 are derived from a geometric series having ratios of 1.58, 1.26, 1.12, 1.06, and 1.03. Thus, successive terms in the R5 series increase by 58 percent, R10 by 26 percent, R20 by 12 percent, R40 by 6 percent, and R80 by 3 percent. The calculated numbers are rounded off as can be seen in figure 18. Each series can be extended upward (fig. 19) or downward by multiplying or dividing by 10. The ISO has published internationally agreed upon numbers in standards "ISO 3" and "ISO 17." More rounded values of preferred numbers have been published in "ISO 497." By applying these standards to products while we convert to the metric system, we arrive at "type-reduction" (inventory reduction) and attendant savings.

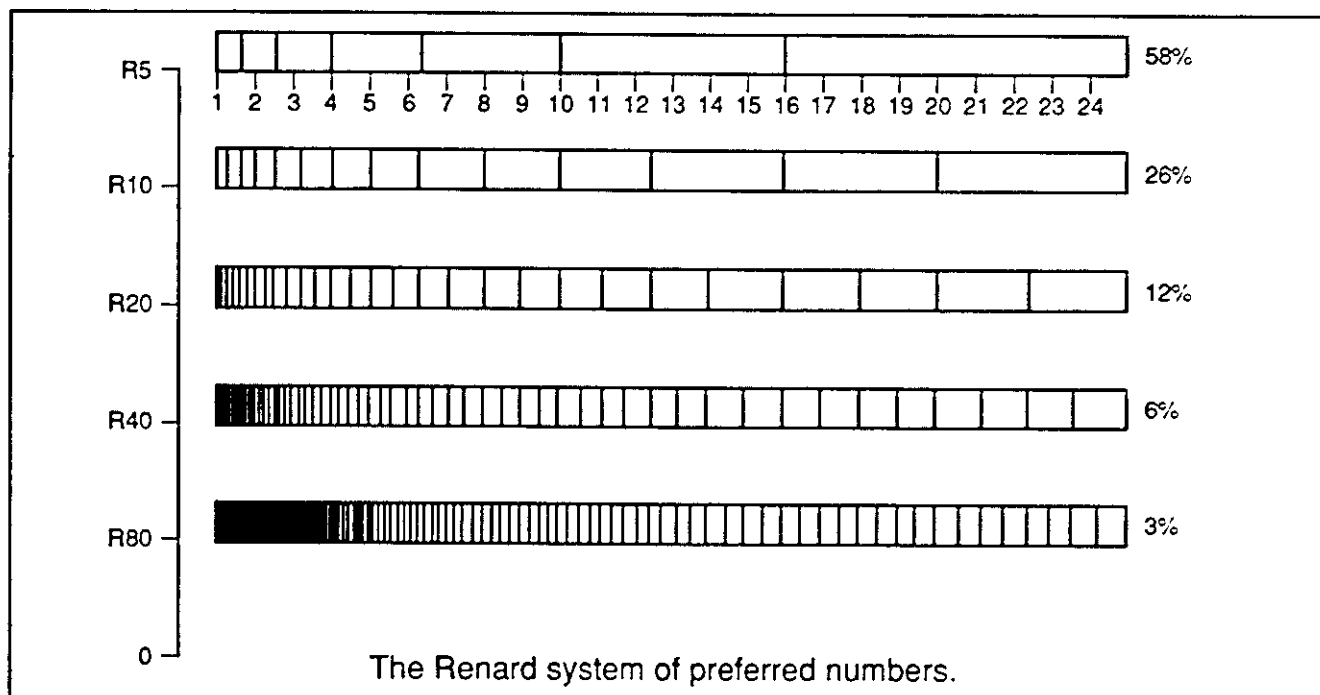


Figure 17. The Renard system.

Figure 20 shows a typical case of type reduction. In the background (left), the 1952 motorcycle is assembled using 7 different thread types and more than 40 sizes of nuts, bolts, and other fasteners. By contrast in the foreground (right), a 1975 "BMW 750" uses only one metric thread and about 16 different sizes. This is type reduction at its best!

B. City of Huntsville

In 1971 and 1972, the City of Huntsville agreed to work with NASA volunteers to install international traffic control signs. Together with the city traffic engineer, we installed international signs including metric speed limit signs. To the best of my knowledge, Huntsville was the first city in the U.S. to take such a progressive step. As shown in figure 21, local television stations cooperated by showing "Going Metric" logos and other metrication material. Local temperatures were announced in degrees Celsius. In figure 22, we advertised the power of the VW automobile as 48 kW. Figure 23 shows a U.S. auto with higher power ratings. In figure 24, a NASA volunteer and a local TV personality pose at a metric speed sign. The MSFC Metrication Committee and City of Huntsville project to convert "Space City U.S.A." into "Metric City U.S.A." was doing very well. In the beginning, local citizens were supportive of the project, however, since the rest of the country was not "going metric," Huntsvillians soon became disenchanted. Due to public opinion and budget constraints, we decided to remove the metric speed signs. I was told that some people claimed they were confused by the speed signs, and that they used the "km" numbers as "mph."

Another example of public reaction to metrication is when the U.S. decided to go metric on a voluntary basis. That was in 1975 when Huntsville had a few gasoline stations that changed their pumps to dispense gasoline by the liter. These stations lost business and soon returned to pumping gasoline by the gallon. At least three things were wrong with this failed approach:

Serial Number	Basic Series			
	R5	R10	R20	R40
0	1.00	1.00	1.00	1.00
1				1.06
2			1.12	1.12
3				1.18
4		1.25	1.25	1.25
5				1.32
6			1.40	1.40
7				1.50
8	1.60	1.60	1.60	1.60
9				1.70
10			1.80	1.80
11				1.90
12		2.00	2.00	2.00
13				2.12
14			2.24	2.24
15				2.36
16	2.50	2.50	2.50	2.50
17				2.65
18			2.80	2.80
19				3.00
20		3.15	3.15	3.15
21				3.35
22			3.55	3.55
23				3.75
24	4.00	4.00	4.00	4.00
25				4.25
26			4.50	4.50
27				4.75
28		5.00	5.00	5.00
29				5.30
30			5.60	5.60
31				6.00
32	6.30	6.30	6.30	6.30
33				6.70
34			7.10	7.10
35				7.50
36		8.00	8.00	8.00
37				8.50
38			9.00	9.00
39				9.50
40	10.00	10.00	10.00	10.00
(Reproduced from BS Handbook 18: 1966, p. 50)				

Figure 18. Basic series of preferred numbers.

Preferred Numbers—Modified Series

1-10			10-100			100-1,000							
R5	R10	R20	R5	R10	R20	R5	R10	R20	R40	R5	R10	R20	R40
1	1	1	10	10	10	100	100	100	100		320	320	320
		1,1			11				105				340
	1,2	1,2		12	12			110	110			360	360
		1,4			14				120				380
1,6	1,6	1,6	16	16	16		125	125	125	400	400	400	400
		1,8			18				130				420
	2	2		20	20			140	140			450	450
		2,2			22				150				480
2,5	2,5	2,5	25	25	25	160	160	160	160		500	500	500
		2,8			28				170				530
	3,2	3,2		32	32			180	180			560	560
		3,6			36				190				600
4	4	4	40	40	40		200	200	200	630	630	630	630
		4,5			45				210				670
	5	5		50	50			220	220			710	710
		5,6			56				240				750
6	6	6	65	65	65	250	250	250	250		800	800	800
		7			70				260				850
	8	8		80	80			280	280			900	900
		9			90				300				950
10	10	10	100	100	100					1,000	1,000	1,000	1,000

Figure 19. Modified series of preferred numbers..

Metric Conversion Provides Type Reduction

IP		SI
7	Thread Types	1
40	Fastener Sizes	15

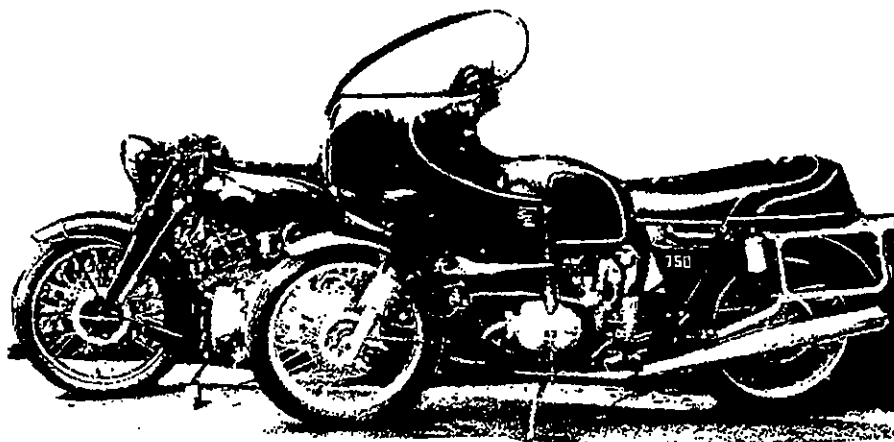


Figure 20. "Type reduction."



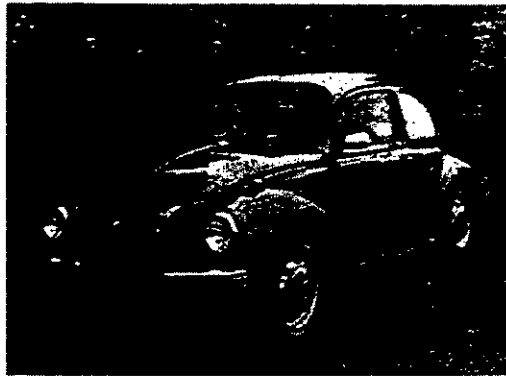
WHNT-TV

CHANNEL **19**

HUNTSVILLE,
ALABAMA

Figure 21. NASA goes metric.

Metric Power



Power:
48 Kilowatts

Figure 22. "Metric power."

Power is Work Per Unit Time

SI derived unit is watt (W)

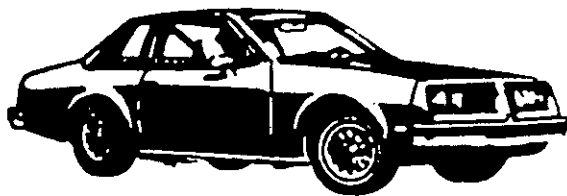
1 watt = 1 joule per second

$1 \text{ W} = 1 \text{ J/s} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^3$

1 W = 1,000 mW (milliwatts)

1,000 W = 1 kW (kilowatt)

1,000,000 W = 1 MW (megawatt)



Power Rating 75 kW

1 joule of work done in 1 second is 1 watt of power.

Figure 23. Power ratings.



Figure 24. 50-km speed limit.

1. The public had not been informed about "SI"
2. Customers thought they were being cheated
3. Local stations had no agreement and no conversion plan.

These attempts by Huntsvillians to go metric stress the importance of countrywide planning and direction prior to the "M-Day." The Australians had a 10-year conversion program, and each industry developed plans which became inputs to the national plan. When "M-Day" arrived in Australia, the public was ready. The Huntsville "M-Day" lacked overall plans. Since the U.S. oil industry had no conversion plan, the local dealers should have developed their own plan and only converted when it would be profitable. Efforts to convert speed signs also lacked an overall plan.

C. Educational Institutions

Alabama schools are in financial trouble. As metrication activities have stressed, our schools would save 20 percent of their math teaching time if it was done in metrics. Presently, we teach two measurement systems, which in our estimation requires 120 percent of the time being used for teaching math using the "customary" system. There will also be time saved in other important subjects, i.e., chemistry, science, and home economics. We look forward to the time when we have only "SI" to teach.

The National Council of Teachers of Mathematics Teacher Learning Center at Reston, VA, has a large display of metric instructional aids. There is no shortage of instructional materials on the market. In addition to the textbooks and workbooks, there are kits, games, manipulative aids, films and filmstrips, charts and posters, slides, transparencies, and records. These teaching aids are provided by vendors from the U.S., Britain, and Canada. The council has compiled a guide of suppliers, but no endorsement of any material is included.

Some metric instruction is taking place in over half of the school districts in the U.S. The majority of teachers and students think that the metric system is easier to teach and learn and that metrics will enhance students' achievement in scientific, vocational, and technical subjects. They believe the metric system will result in fewer errors and that metric measurements are more accurate.

VI. SPECIAL CONVERSION ITEMS

A. Standardization

International standards and the participation by the U.S. in their development are becoming more important as we move toward metric conversion. The metric standards required by the U.S. to implement conversion must be compatible with international standards. If they are not, U.S. products may be barred from export markets or returned for modifications (like the General Electric appliance). Since the U.S. has more than 400 organizations that issue standards, we have the manpower to increase our participation in international standards development, especially with the ISO and International Electrotechnical Commission (IEC). Actually, the growing influence of the metric system of units on international standards and the increasing competitive importance of metric specification for products in the international market prompted congress to include the "metric usage" provisions in the Omnibus Trade and Competitiveness Act of 1988. Each Federal Agency is now responsible for implementing metric usage in grants, contracts, and other business activities, to the extent economically feasible. We think that by offering to buy metric products and services, Government can help industry make the transition and demonstrate a commitment to the metric system of measurement.

The metric units standard used by NASA is "FED-STD-376B, Preferred Metric Units for General Use by the Federal Government." If we compare this document with other documents that are used by every industrial nation in the world, we find that the common reference in all is "ISO 1000-1992." This standard is maintained by the ISO, located in Geneva, Switzerland. Figure 25 lists the organizations of ISO. The American National Standards Institute (ANSI) is the U.S. member on the ISO general assembly, as shown in figures 26 and 27. Other member countries shown are: JISC-Japan, DIN-Germany, AFNOR-France, BSI-United Kingdom, UNI-Italy, CSA-Canada, and SAA-Australia. The standards generation and technical exchange is assigned to technical committees/subcommittees/working groups: a preparatory working group and an ad hoc working group. As the names imply, one prepares standards and the other provides ad hoc support. The U.S. has over 80,000 nationally recognized standards, and the standardization task is tremendous. Nevertheless, metrication presents an excellent opportunity to reduce product inventory costs by minimizing the number of standards.

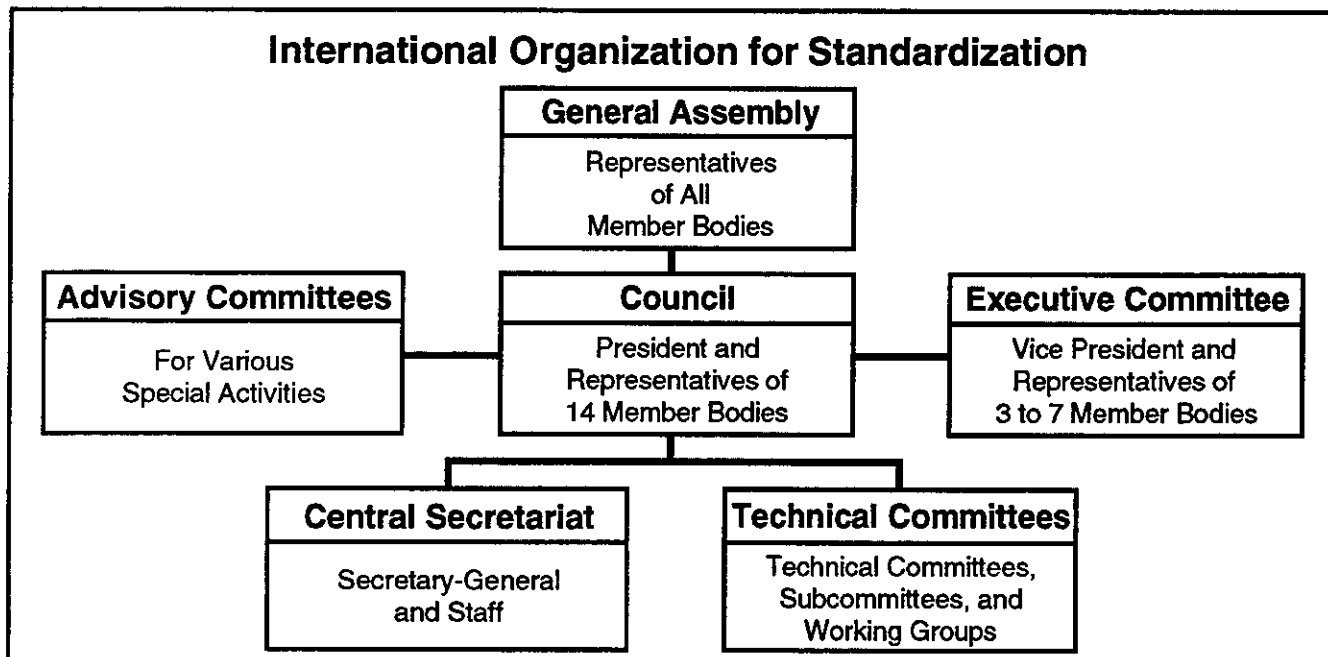


Figure 25. International standards organization.

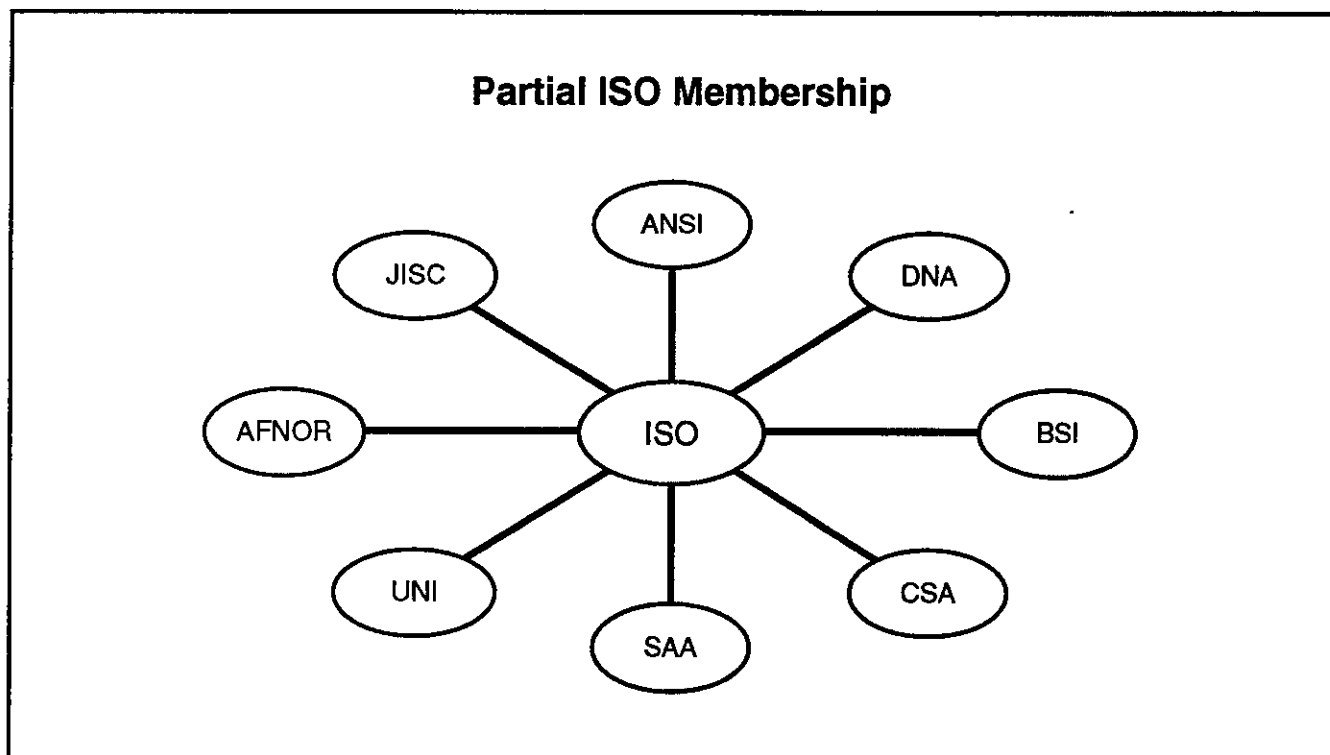


Figure 26. Partial membership structure.

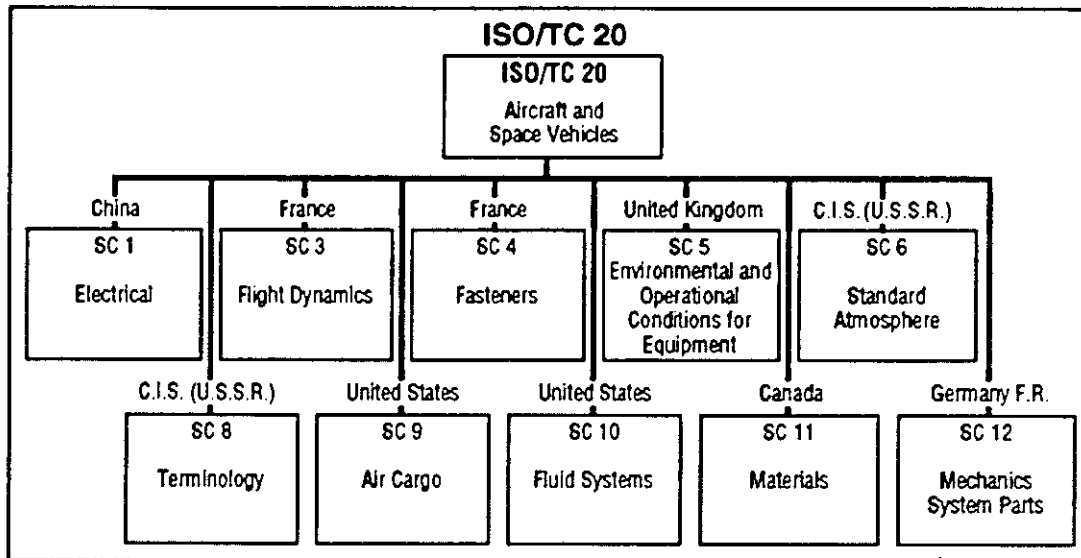


Figure 27. ISO/Technical Committee TC20.

The "ISO 9000-Series" of quality certification and registration documents have national counterparts in most countries. The U.S. counterpart is MIL-Q-9858. From a metrication point of view, I do not think that it matters how many similar standards there are at this time, because as we begin exporting metric products to other countries, each partner will agree to minor changes here and there. By harmonizing the different standards, we can accept products manufactured to these harmonized international standards. Later on, we can minimize U.S. standards, German standards (DIN), Japanese standards (JIS), British standards (BIS), etc., and combine them into ISO standards to be used for global trade. As we do this, the number will dwindle—only the best ones will survive, and we know which are the best!

B. Machine Shop Conversion

Eventually, most manufactured products will have to be made to metric dimensions. It is important to emphasize that none of the problems involved in converting a machine shop to work in metric units presents any great difficulties. The timing of when to change machinery and other measure-sensitive equipment must be carefully planned. The importance of planning cannot be overemphasized. The changeover will involve both item and money, e.g., determining how long to use overlay metric scales versus purchasing new equipment is done by trade analyses.

Components manufactured to metric dimensions involve no more work and are no more difficult to produce than their "inch-pound" counterpart; actually production will be easier once the new units are established. New measuring equipment will usually be required, and it may be necessary to replace or convert some machine tools. Usually changes are easy to make. Trades will show several possible courses of action and many decisions have to be made. Not everything needs to be converted. There is no need to change unless some real benefit can be obtained. The impact of metrication on people, on the flow of information, and on the methods used must be considered and the required training must be provided. Initially, both metric and inch-pound components will be manufactured in the same shop, perhaps on the same machine tools. No two shops will have the same problems, and there is no unique recipe to follow. "Management must think globally and act locally!" This is a new paradigm that Ford Motor Company is promoting to their management.

The first and probably the most important step in planning the machine shop conversion is to develop an overall plan. When reference is made to machine tools like the milling machine in figure 28 and the lathe in figure 29, we should note that these machine tools do not necessarily have to be totally converted. Only the features needing fine adjustment of cutting tools, dials, feed-screws, or vernier scales need to be modified to read in metric units. All machine tools, irrespective of their make or type, can be used to produce either inch-pound or metric products. Modifications should only be made to maintain or increase efficiency and production. Unnecessary modifications waste money. Dials can be modified as shown in figure 30 which shows the addition of a metric scale on an existing dial calibrated in inches. A relatively simple solution is to mark the metric graduations on a flexible, toothed belt, driven by a gear drum which also carries inch graduations as shown in figure 31. A more accurate conversion can be obtained by a metric dial geared to the "inch" lead screw (fig. 32). If the machine has digital readout equipment, it generally is a matter of switching from inch-pound to metric units. The same goes for optical position indicators.

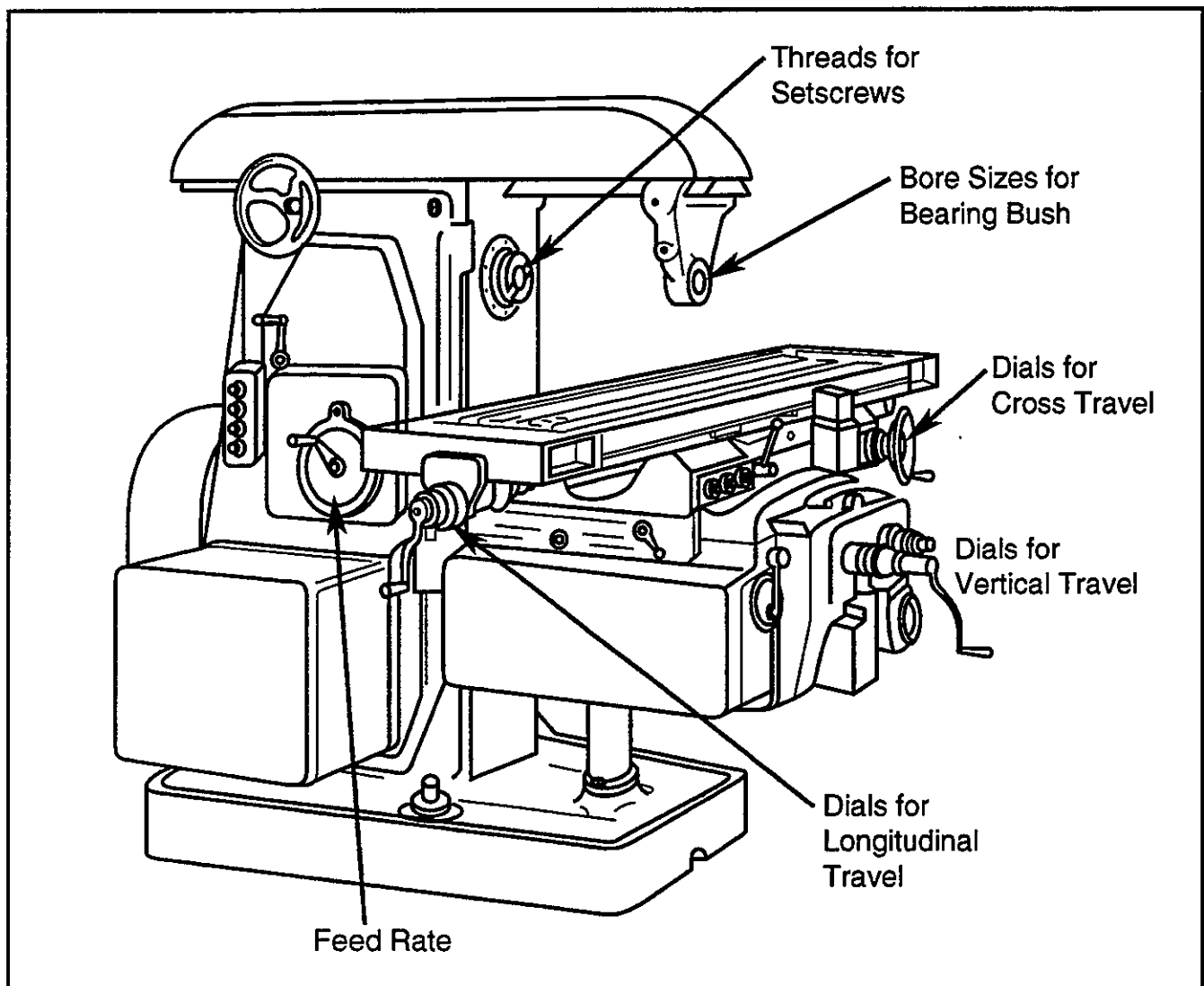


Figure 28. Milling machine.

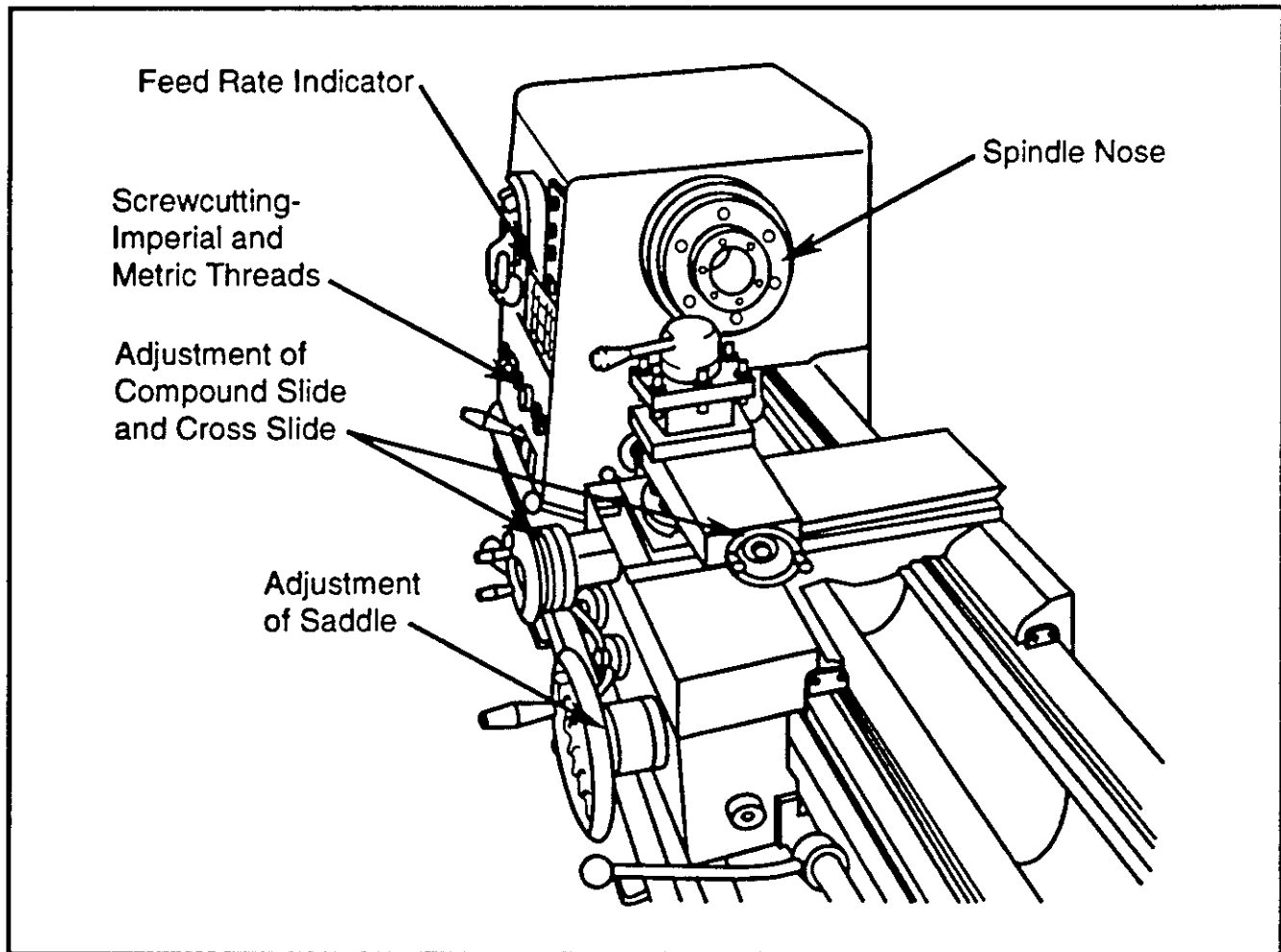


Figure 29. Lathe.

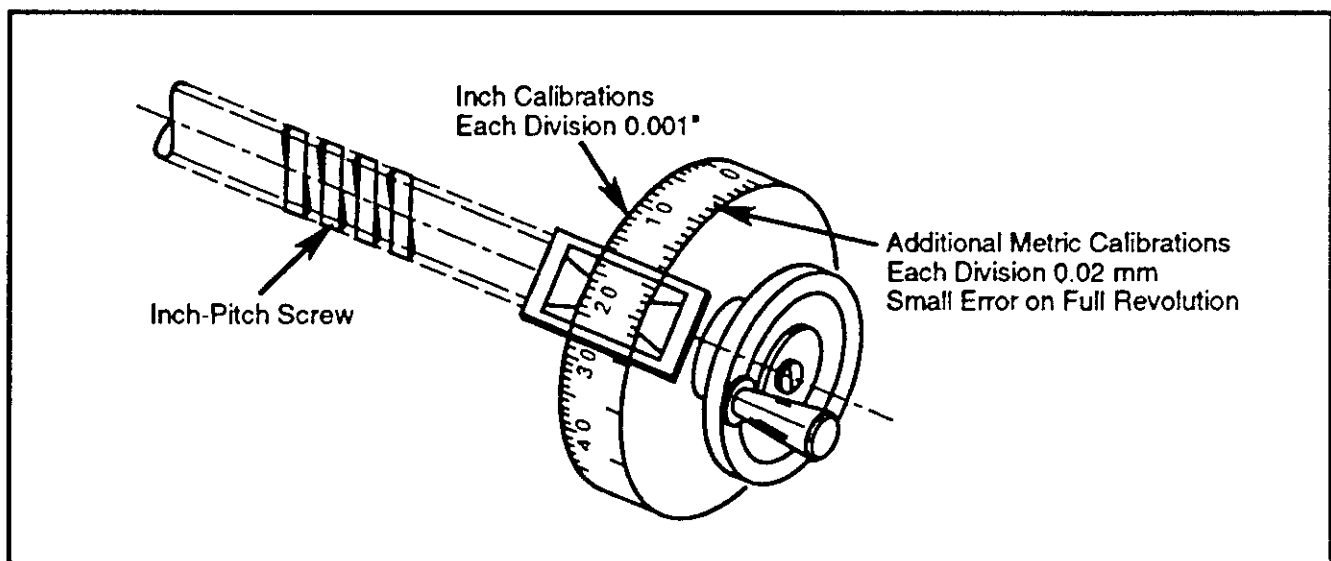


Figure 30. Conversion dial—modification.

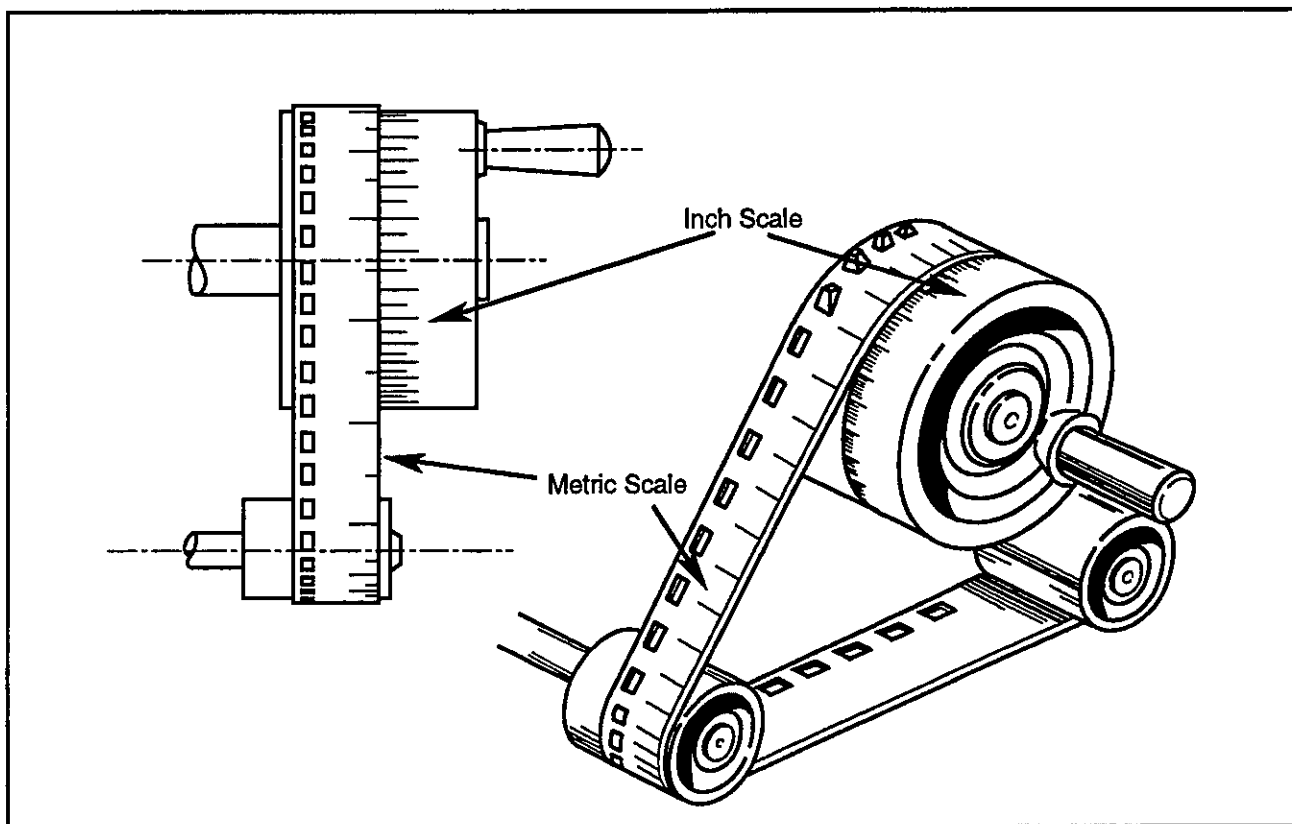


Figure 31. Simple conversion modification.

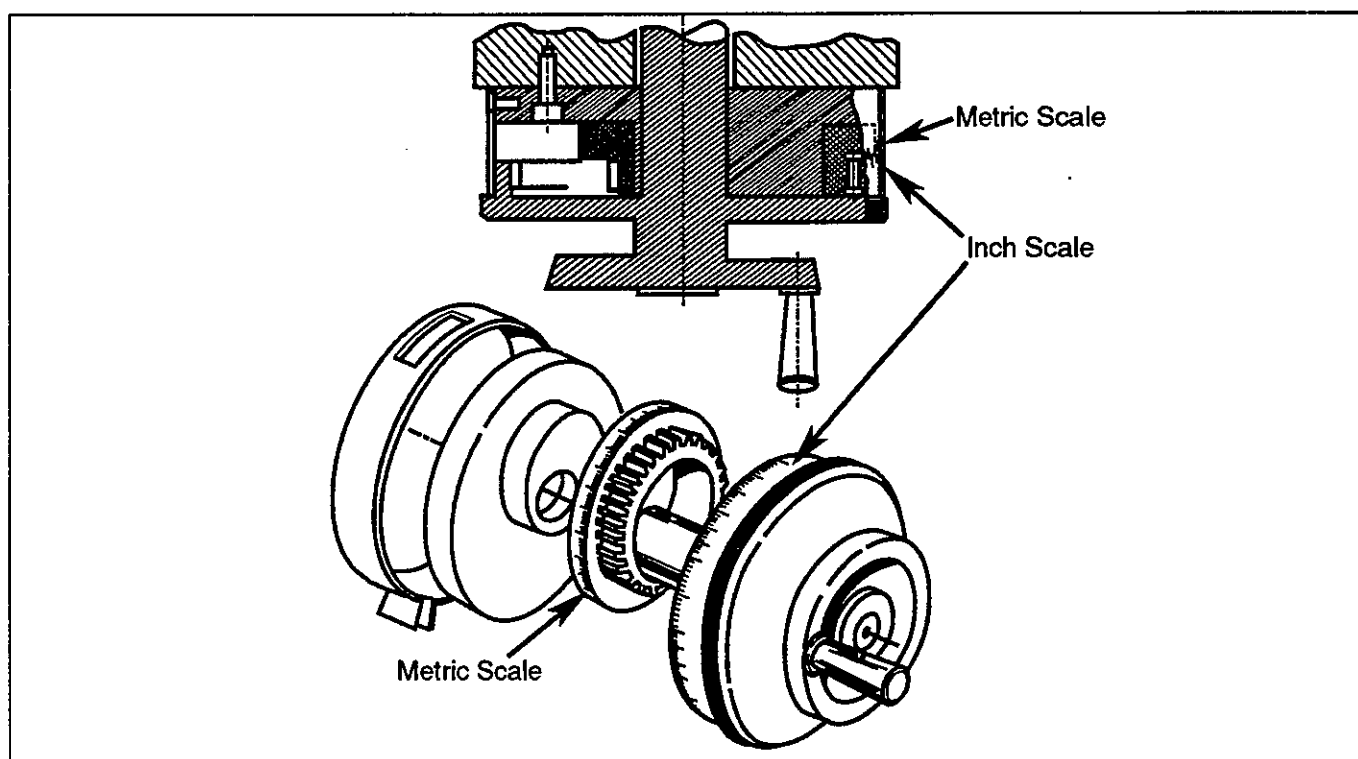


Figure 32. Accurate conversion modification.

C. International Paper Sizes

International paper sizes consist of three series of paper sizes, the A-series, the B-series, and the C-series. Each series of paper sizes starts with one basic size. Succeeding sizes are determined by a geometric relation with the previous size. ISO has adopted the A-series as the preferred series, the B-series and a modified C-series are part of the "ISO R216" standard. There are no immediate plans to convert the presently used sizes in the U.S. to international paper sizes. However, most copying machines sold today are capable of accepting both inch-pound and metric paper sizes.

The basic paper size (A0) of the A-series has an area of 1 m^2 ; the ratio of length to width is the square root of 2 (fig. 33). The series progresses in size by halving the larger dimension as shown in figure 34. Each size folded in half produces the next smaller size. Proportion always remains the same. The same proportion is used for microfilm and for microfiche.

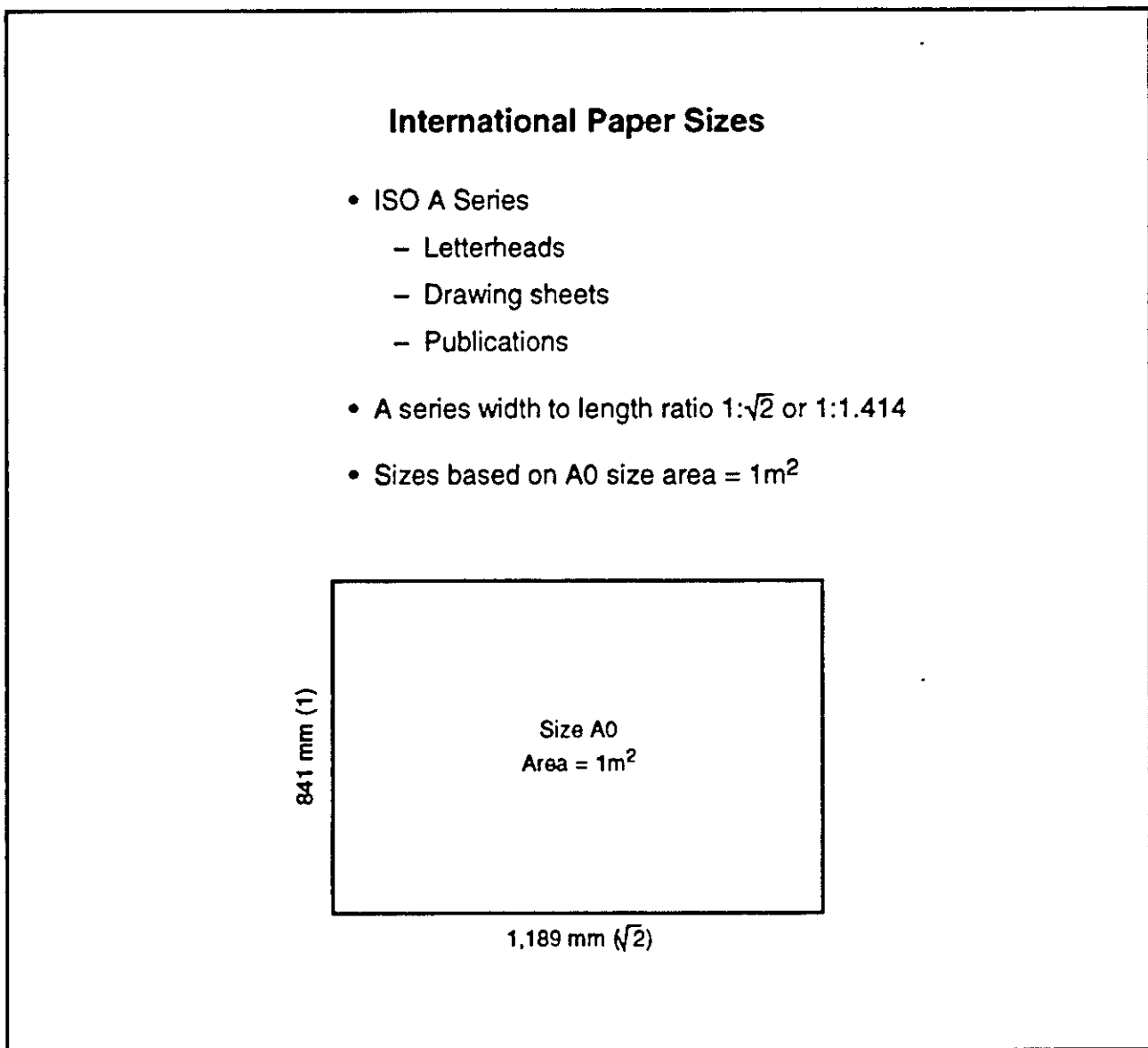
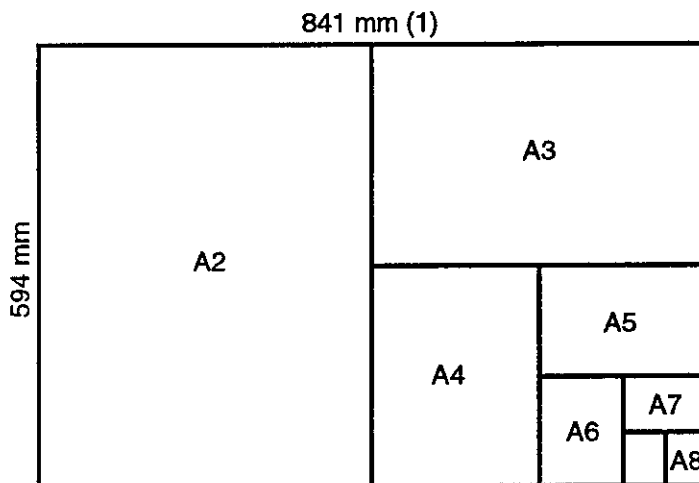


Figure 33. International paper, ISO A-series.

International Paper Sizes

- Each size folded produces next smaller size.
- Proportion always remains the same.



No.	Size mm
A0	841×1,189
A1	594×841
A2	420×594
A3	297×420
A4	210×297
A5	148×210
A6	105×148
A7	74×105
A8	52×74
A9	37×52

Figure 34. International paper dimensions.

The basic paper size (B0) of the B-series has an area of the square root of 2 m^2 . The basic paper size (C0) of the C-series has an area of the 4th root of 2 m^2 (or 1.189 m^2).

Some NASA field Centers (GSFC, MSFC, and JPL) use ISO paper sizes for promotional and international correspondence. Other Federal agencies that use ISO paper sizes include U.S. Department of Commerce, U.S. General Accounting Office, and the Internal Revenue Service.

D. Training

Training is an important aspect of metrication. We have several approaches to training. Most companies promote specialized training for different groups of employees (managers, engineers, administrators, secretaries, shop personnel, etc.). This group approach to training is oriented to the different needs of the company requesting training.

Organizations that want to establish their own training programs may want to purchase materials like the USMA tape "All About Metric" and/or the "Freeman Training/Education Metric Materials List," an excellent resource book for all types of teaching materials. Both items are listed in figure 35. Another page of supplies and training aids is shown in figure 36.

U.S. METRIC ASSOCIATION

for 78 years the leader in providing metric guidance and information to U.S. companies

OFFERS SPECIAL PRICES FOR A LIMITED TIME TO MEMBERS

on its renowned publications to make metric a reality at your company: new editions of updated, expanded materials on converting your company, training employees, and securing metric parts & components.

Guidance for Companies Considering Converting Their Operations to Using the Metric System. (128-page book). Contains information on how to convert every aspect of your company's operation to metric usage, including case studies of Xerox Corp, Caterpillar, and the ISO 9000 certification experience of one company. This invaluable, comprehensive book available FREE only to USMA company members. [membership information below]

[] ***All About Metric Video Tape*** series with a detailed reference manual and an instructor manual. This 3-video-tape package provides information on why the U.S. is converting to metric system usage. Gives tips on how to remember the everyday metric units and sizes. Gives rules for using metric rules and symbols. Discusses technical units used in industry. *Very instructor/learner friendly.*

The 80-page, profusely illustrated, reference manual furnishes details on what is shown in the video tapes. The instructor manual contains 50 master pages which can be made into overhead projector transparencies to assist the instructor in giving the course. It also has auxiliary data for the instructor to use, including masters for pages of questions the instructor can use to check whether employees understand the lessons given.

Current price, \$500. Special price, to members, if ordered before April 30: \$350

[] ***Freeman Training/Education Metric Materials List.*** A 300-page metric bibliography that lists all types of metric system teaching materials, including books, video tapes, computer software, workbooks, conversion charts, posters, drafting guidelines, standards & engineering data, construction data, metric training aids, lab equipment, charts, rulers, meter sticks, etc. [The first printing is sold out, and it is being updated with new, current entries. Available about Mar. 1]

Special price, to members, if ordered before April 30: \$30

[] ***Metric Vendor List.*** A 150-page book that list companies (with their addresses, telephone numbers, and products) which produce metric-system-based industrial products, parts, or components. [The first printing is sold out, and it is being updated with many new entries. Available about Mar. 1.]

Special price, to members, if ordered before April 30: \$25

USMA MEMBERSHIP PER YEAR:

[] \$150 for companies, and includes 6 issues of each bimonthly *Metric Today* publication, plus a copy of *Guidance for Companies Considering Converting Their Operations to Using the Metric System.*

[] \$30 for individuals, and includes one copy of each bimonthly *Metric Today* publication for the year.

Just check the items you want to order, enclose this order form with your remittance (a \$2 fee is charged if there is no remittance and billing is required), and mail it to:

U.S. METRIC ASSOCIATION
10245 Andasol Avenue
Northridge CA 91325-1504

Telephone & FAX: (818) 368-7443

Figure 35. U.S. MA metric materials.

METRIC SUPPLIES AND TRAINING AIDS

U.S. METRIC ASSOCIATION • 10245 Andasol Ave., Northridge, CA 91325 • (818) 368-7443

SI METRIC STYLE MANUAL FOR WRITTEN AND COMPUTER USAGE. Provides the rules for using the SI version of the metric system, including the correct short forms (symbols) to be used with computer systems (& message transmission systems) that use only capital letters and do not have a superscripting capability. Also indicated are the non-SI metric units approved for use with SI, and obsolete metric units which are not acceptable.

1 to 9 copies (ea) \$1.50 10 to 99 copies (ea) \$1.25 100 or more copies (ea) \$1.00

USMA's METRIC UNITS OF MEASURE & STYLE GUIDE. A booklet that lists SI metric units and symbols, lists the rules for using them, and provides a table of conversion factors for the commonly used units.

1 to 9 copies (ea) \$1.00 10 to 99 copies (ea) \$.50 100 or more copies (ea) \$.45



METRIC RULER. Sturdy plastic, white with black type, 200 mm in length. Shows mm and cm markings.

Package of 10 \$4.00

Package of 100 \$28.00

POSTER: *Metric Units for Everyday Use.* A 4-color wall chart that describes metric units for length, area volume, mass, and temperature. Size: 73 cm high by 106 cm wide.

Each \$3.75

Durable, plastic **MEASURING TAPE,** 50 cm (1.5 m) long. Shows mm, cm, and dm divisions (marked in blocks) on bright, primary colors of red, blue, yellow, in alternating 10 cm (1 dm) segments. Will not fray or stretch.

Each \$1.75

Package of 10 \$16.50

Package of 20 \$28.00



CELSIUS THERMOMETER. Mounted on white plastic. Measures about 5 cm wide by 15 cm long. Registers from -30 °C to 50 °C.

Package of 10 \$8.50

Package of 100 \$60.00

MEDICINE & METRICATION by Dr. Howard M. Faulkner. 36-page booklet includes a brief outline of metric system usage and gives equivalent inch-pound and SI metric apothecary units and symbols. Also lists metric measurements for medication dosage, patient body measurements, sterilization, etc. Included is USMA's 13-page *Metric Handbook for Hospitals*.

1 to 9 copies (ea) \$1.25

10 to 99 copies (ea) \$1.00

100 or more copies (ea) \$.75

GO METRIC BUMPER STICKER. Deep blue background with orange lettering.

Package of 10 \$1.75

Package of 100 \$14.00

THE INTERNATIONAL SYSTEM OF UNITS (SI). A 1-page comprehensive diagram that shows the SI units and their interrelationships. Includes all SI base and derived units.

Package of 50 \$3.00

Package of 100 \$4.50

USMA NEWSLETTER SUBSCRIPTION. Published every other month. Provides up-to-date news on metric developments in the U.S. and abroad. Gives data on new metric articles and publications. Reports on metric activities of various groups, companies, industries, and organizations. USMA membership is included with newsletter subscription.

PER YEAR: ☐ Individual Membership (USA).....\$20.00 ☐ Company/Agency Membership...\$100.00
☐ Individual Membership (foreign) \$25.00 ☐ Lifetime Membership..... \$300.00

(lifetime membership available only to individual members)

Figure 36. Training aids.

Another option to training is the current low-key approach to metrication which eventually will teach every citizen that metrication will improve living conditions because a decimal system is so easy to use in everyday living. **Everyone will soon learn how foolish we are to cling to the "abacus" when we have the "computer" at our disposal.**

VII. FUTURE OF METRICATION

The Federal grant process and other business activities have shown mixed progress. The Federal Aid Highway Program is going full speed toward metric design and construction, whereas the housing and education agencies have not decided on metric requirements for grants. The Alcohol, Tobacco, and Firearms Bureau converted the liquor bottle sizes many years ago without any real objections from customers. In the process of conversion to metric bottles, there was a large reduction of the overall number of bottle sizes with attendant cost savings. All Federal Agencies can profit from the ATF experience.

The Federal grant funding will increase the use of the metric system. Industrial relations between domestic and foreign markets will lead to an increased push on the U.S. to become part of the metric world. To buy and sell internationally, companies must use the metric system, stop the dual production lines, and compete in the global market with American metric products.

The most metric U.S. industries are farm and earth-moving equipment, automotive, wine and spirits, photographic equipment and supplies, and soft drinks.

From appliance cords to Federal grant highways and office buildings, the daily lives of those involved in construction, manufacturing, and exporting are changing, the United States is quietly going metric. No longer are we willing to hide our heads in the sand like the cartoon in figure 37 implies.

Our younger engineers know both "inch-pound" and "SI" and cannot understand why we do not convert. Some are promoting metrication in their work environment, but they are cautious because they have been told that inch-pound numbers are what is expected in their analyses and designs. Perhaps by the end of the century when the "grey heads" have retired we will be fully metricated. We all like to hold on to the "familiar" including an obsolete measurement system. We have a choice. Let's chose "SI."

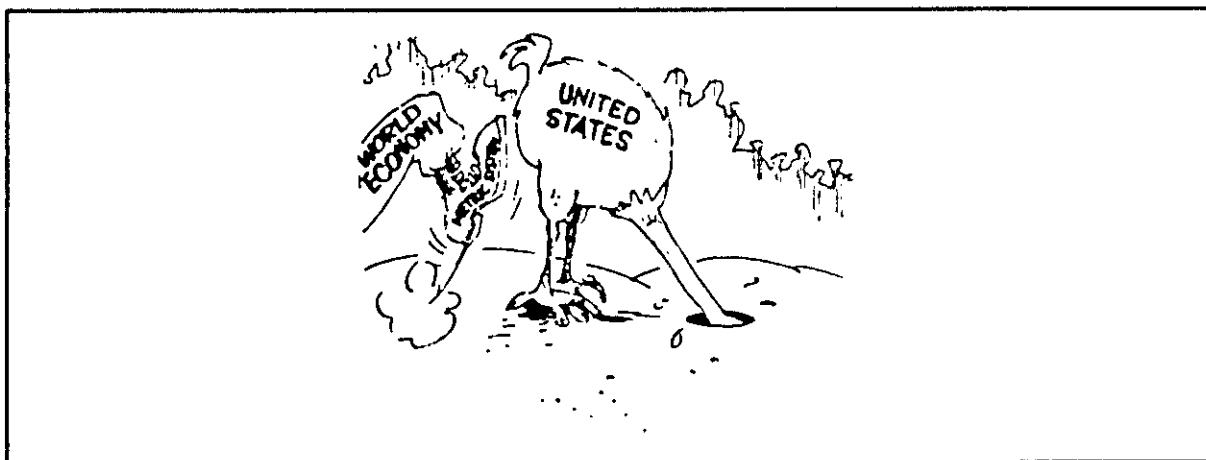


Figure 37. "The black hole."

BIBLIOGRAPHY

1. NASA Management Instruction, NMI 8010.2A, "Use of the Metric System of Measurement in NASA," June 11, 1991.
2. "NASA Metric Transition Plan," February 2, 1992.
3. Public Law 94-168, December 23, 1975, amended by Public Law 100-448, August 23, 1988, and Executive Order 12770, July 25, 1991, "Metric Conversion Act," "Trade and Competitiveness Act," and "Metric Usage in Federal Government Programs."
4. Mechtly, E.A.: "The International System of Units." Second Revision, NASA SP-7012, 1973.
5. Lange, E.: Information on the Metric System and Related Fields." NASA TM X-3449, November 1976.
6. McCracken, J.R., and Carver, G.P.: "Recommended Agency Procedures for Implementing Federal Metric Policy." NISTIR 4855, May 1992.
7. Carver, G.P.: "A Metric America: A Decision Whose Time Has Come—For Real." NISTIR 4858, June 1992.
8. Carver, G.P.: "Metrication: An Economic Wake-Up Call for U.S. Industry." NISTIR 5154, March 1993.
9. "Freeman Training/Education Metric Materials List," 1994 Edition.
10. "Metric Conversion, Future Progress Depends Upon Private Sector and Public Support," GAO/RCED-94-23, January 1994.
11. Alabama Department of Transportation Guide, "Moving to Metric," April 1994.

APPENDIX A
REMARKS BY THE HONORABLE GEORGE E. BROWN, JR.

REMARKS BY
THE HONORABLE GEORGE E. BROWN, JR.
AT THE NATIONAL METRIC CONFERENCE
ROCKVILLE, MARYLAND
SEPTEMBER 30, 1993

METRICATION NOW FOR AMERICA'S ECONOMIC COMPETITIVENESS

I am extremely pleased to be here today at the National Metric Conference, and to be able to spend some time with my many friends who share my conviction that the time has come for the United States to join the rest of the world in unqualified support of the SI metric system of measurement.

While to some, support of metric may seem quaint, eventual conversion of our economy to the metric system is both essential and inevitable. Precise measurement is the underpinning of the world economy and metric, except in the United States, is the worldwide language of measurement. Everything from paper sizes to bolts is being standardized throughout the world and metric is the catalyst. These products are now manufactured, measured, packaged, and transported in metric. Finally, after a gestation period of a couple hundred years, the inherent beauty and simplicity of the SI metric system has won converts throughout the world. This trend is leading to efficiencies in all sectors of the world economy that could not have been dreamed of a few decades ago.

However, standardization also inevitably leads to rejection of non-standard products. We are not that far away from the time when many nations will begin stopping non-metric products at the border. The sooner we face the fact that our traditional standards of measurement are anything but standard today, the better off we will be.

There is another very simple reason to convert our economy to metric. It is that the metric system makes sense. I'm sure when the King of England was all powerful, there may have been a good reason for the length of his foot to be the standard foot. When we knew little about temperature or pressure or weight, there were presumably very logical reasons to adopt the various English standards of measurement that seem quite arbitrary today. However, in today's world, we would be remiss to keep relying on a measurement system with haphazard units of measurement when a scientifically based alternative like metric exists. Metric has developed in context of our scientific knowledge. It takes into consideration the interrelationship between units. The result is a measurement system which is elegantly simple and easy to use. When coupled with standard metric sizes, measuring in metric can lead to major business efficiencies and an improved bottom line.

With such a compelling case for conversion, we need to ask ourselves why do the American people continue to prefer the Yugo of measurement when the Cadillac is theirs for the asking. Why are so many of our fellow citizens uneasy about conversion to metric? The failure of our educational system to embrace metric is one obvious reason. We need to teach the truth about metric, teach it often, and teach it until it sinks in. Metric is a logical system of measurement that shows relations among sizes and units even without your asking. Since it is base ten numerical system, it is easy to use. Once metric is taught in earnest for a few years, young people will wonder why anyone would think of using any other system. Children raised on metric would rebel against having to do computations based on how many

quarts are in a peck or how many acres are in a square mile when the equivalent metric-based operation simply involves moving a decimal point.

Therefore, the time has come to pull our collective heads out of the sand and to look around at the many benefits metric literacy and usage can bring to our society. Wider usage of metric in our businesses clearly can increase the competitiveness of U.S.-made goods in world markets. We are only hurting ourselves if we remain the only industrialized nation to cling to the Olde English system of measurement.

A new day for metric in the United States began in 1988 with the passage of the Metric Usage Act. This Act established the metric system as the preferred measurement system for United States trade and commerce and required the Federal procurement and other business-related activities be conducted in metric to the extent practicable by the end of 1992. It was hoped that the buying power of the Federal government would give companies the incentive to begin converting all their operations.

Implementation of the Metric Usage Act got off to a slow start, but the issuance of Executive Order 12770 by President Bush on July 25, 1991 led to the Act being taken more seriously. The Executive Order reaffirmed the federal commitment to metric conversion and designated the Department of Commerce to direct and coordinate the federal conversion effort. The Executive Order also authorized the Secretary of Commerce to establish and chair the Interagency Committee on Metric Policy and the Metrication Operating Committee (MOC). The interagency MOC oversees a series of subcommittees, each dealing with a specialized area, such as procurement or public education and awareness.

The Order further required the Secretary of Commerce to make an annual progress report to the President and, by October 1, 1992, to give the President recommendations regarding any additional measures needed to achieve the full economic benefits of metric usage.

About the same time, the Commerce Department appointed a strong program manager for the metric program and transferred responsibility for coordination of metric conversion to the National Institute of Standards and Technology.

I remember being especially pleased by the Executive Order at the time because it finally demonstrated the commitment of the Bush Administration to achieve the objectives contained in the Metric Usage Act. This commitment led all fourteen federal departments and almost all the federal agencies to issue guidelines for their metric conversion activities, and in most cases to develop metric conversion plans.

Unfortunately, there have been exceptions, such as the Department of Education, which has a key role to play as chair of the interagency Subcommittee on Education and Public Awareness. As industry and businesses increasingly convert to metric usage, the education community bears the responsibility to prepare students in all measurement-sensitive subject areas for employment in the metric workplace. This can be accomplished more rapidly and effectively with firm Department of Education backing.

This brings us up to the present. Therefore, in closing, I would like to summarize where I feel we are in metric conversion and to make a few suggestions on what should be done in the next few years to make our dream of a more efficient, metric-friendly America a reality.

While metric conversion has proceeded more slowly than we may have liked, it has proceeded to the point where we are on the threshold of some major steps forward. A great deal of preparatory work

has brought us to the point where much of the planning for conversion of the Federal government to metric has taken place. Our focus should now be on taking those few remaining steps which must occur before metric conversion takes on a life of its own.

First, I would like to see the Clinton Administration find a way to take over ownership of the Bush Executive Order on metric. Soon after President Bush issued his executive order, some government programs, such as construction, wholeheartedly endorsed metric. If there is a reaffirmation of metric conversion from a high level in the Clinton Administration, I believe other agencies and programs will follow suit.

Secondly, I would like to see someone in the White House, perhaps in the Office of Management and Budget, step forward to discuss each Agency's metric conversion plan with the current political appointees who can make or break the conversion effort. They must understand what the law expects of them and see that there are people above them in the Government that know and care about what they are doing to make metric conversion a success.

Thirdly, I hope that senior management of the Department of Commerce will step forward as strong leaders in the day-to-day policy level decisions which can make metric conversion a success. Other agencies must understand that Commerce is taking its lead agency responsibilities seriously that it is available to help with conversion efforts.

Fourth, it is time for the Clinton Department of Education to stand up and be counted in metric. Since the metric system of measurement is the measurement system of all science and technology, metric education must be included in any comprehensive national educational improvement plan. For instance, President Clinton's Education 2000 initiatives states that students in the United States will be first in the world in mathematics and science achievement at the beginning of the next century. This effort is doomed to failure unless these U.S. students are fluent in metric.

Fifth, I understand the Secretary of Commerce's Metric Report, required under the Metric Usage Act, was sent to the President with recommendations for further action. This report should be scrutinized and acted upon.

Finally, I realize that metric conversion cannot be accomplished singlehandedly by the Federal Government. State and local governments and their education communities must become more involved, and the private sector must be an integral part of the metric conversion effort. Industry, through its companies, trade associations, and engineering and professional societies, can play a major role by stressing the importance of metric to being economically competitive. Everyone in this room has a role. So let us pull together and get the job done. You have my word that I will do my fair share.

APPENDIX B
PUBLIC AWARENESS

Public Awareness

- **Awareness improves acceptance**
 - Recognize relationship
 - Driver/User awareness
 - Australian metrification
 - British metrification
- **Agency, Public, Private Awareness**
 - Public-at-large
 - Motorists
 - Consultants/Land Surveyors
 - Roadbuilders/Contractors
 - Vendors/Suppliers
 - Fabricators
 - Colleges/Universities
- **The need to follow national leadership**
 - Will not be able to go "our own way"
 - Department of Commerce
 - SASHTO
 - AASHTO
 - FHWA
- **The Canadian example**
 - National TV ads
 - Public service announcements
 - Print media
 - Posters/Bill boards

Education and Training

- Training is important/High priority
- NHI and GSA present one-day training
- Train all personnel
- Obvious training methods
 - Outside training
 - Agency training
 - On-the-job training
 - Self-training by literature
- Training needs
 - Train the trainer
 - Formal
- Training needs designed for Agency
 - Probably should be tailored
 - Given at right time - not too early
 - Not too much
- Training should
 - Designed to fit office
 - Train each individual
 - Be timed near transition
 - Increase public awareness and interest

Hard and Soft Criteria

While developing metric standards, controls and criteria, the question of hard versus soft conversion arises. A SOFT conversion is an exact re-stating of a conventional U.S. measurement in metric terms. This is often undesirable because the metric terms may have odd values (i.e., a lane of traffic may be 3.658 meters wide). When employees have to add the total widths of four lanes to determine the road width, the math becomes more difficult and introduces errors.

A hard conversion is a statement of a previous dimension in convenient, rounded metric units. For example, it would be easier for lane widths to be stated as 3.6 meters of 3.7 meters. These convenient units are much easier to remember. In general, highway standards lend themselves readily to hard conversion.

Whenever possible, hard conversion should be used. The US DOT, FHWA, AASHTO, the Construction Metrication Council of the National Institute of Building Sciences, and many others encourage hard metric conversion to the extent practical.

The desirable use of hard conversions will in practice be tempered by the need to continue existing values until equipment and supplies are exhausted; however, many instruments now use digital readouts which at the press of a button convert values to the metric.

Soft Metric

Soft metric means "No Physical Change".

This implies the product in question will not be physically modified to be used in a metric project.

Over 95% of currently used building products will not be physically modified to be utilized in metric construction.

All that is required is that the product literature and engineering data on these products be available with metric dimensions.

It is acceptable if product literature contains both metric and english dimensions.

Since product literature costs can be substantial, firms without metric product literature need only develop a supplement to their existing literature. Supplements will be accepted as submittals for an interim period.

There is no problem with competitive availability of soft converted products on a metric project, since these same products are competitively available today.

In the future, as standard international metric product sizes are developed by ISO (International Standards Organization) or another standards organization, these products may undergo modification to be compatible in the world market.

Hard Metric

Hard metric means “Product Requires Physical Change”.

The product in question must be physically modified in order to be efficiently utilized in a metric project, which is planned on a metric grid.

A handful of currently used building products must undergo hard conversion to new metric sizes.

Examples of products that must be physically changed:

- Air diffusers and grilles (lay-in type only)
- Brick
- CMU
- Drywall
- Fluorescent Lighting Fixtures (lay-in type only)
- Raised Access Flooring
- Suspended Ceiling Tiles and Grids

Rounding and Conversion

Conversion of an existing Code Requirement

To professionally round code requirements, the following process should take place.

- **Step 1. Determine the nonoffending direction.**

1990 BOCA Article 514.7 requires 36 inches (914 mm) of unobstructed pedestrian walkway width. However, 914 mm is not a clean, rational number. It should be rounded to facilitate the cleanest construction possible.

Narrower offends the Code. The nonoffending direction is larger, so it is preferred to round larger.

Rounding and Conversion (Cont.)

- Step 2. Select the largest feasible multimodule.

- The most preferred multimodule, 6000 mm is not feasible.
- Next preferred multimodule, 3000 mm, is also not feasible.
- 1200 mm is feasible, so this represents a good choice.
- if 1200 mm is determined too large, try the next multimodule.
- 600 is offending, and 2 X 600, 1200, has been tried.
- 300 yields 300, 600, and 900 mm, all offending dimensions.
- 300 also yields 1200, which has been tried.
- 100 yields 1100 and 1000, the next best choices.

Every effort should be made to keep design dimensions in increments of 100 mm, the basic module, or multimodules.

If narrower must be used, submodules of 100 are required.

- Use of 50 yields 950 mm.
- Use of 25 yields 925 mm.
- Use of 20 yields 920 mm.
- 914 mm can be used, but preferred dimensions are recommended.

In each case, the user must determine the acceptable choice, but the professional is encouraged to present clean, rounded metric dimensions as alternatives.

Simple mathematically converted dimensions should not be used.

APPENDIX C
CONVERTING DIMENSIONS

1 Inch = 25.4 mm

63/64 Inch = 25 mm

THINK:

1 Inch = 25 mm

4 Inches = 101.6 mm

3 - 15/16 = 100 mm

THINK (FOR BASIC MODULE):

4 Inches = 100 mm

(but lose 1/16 Inch)

8 Inches = 203.2 mm

7 - 7/8 Inches = 200 mm

THINK:

8 Inches = 200 mm

(but lose 1/8 Inch)

12 Inches = 304.8 mm

11 - 13/16 Inches = 300 mm

THINK:

12 Inches = 300 mm

(but lose 3/16 Inch)

2 Feet = 609.6 mm

1 Foot, 11 - 5/8 Inches = 600 mm

THINK (FOR PLANNING GRID):

2 Feet = 600 mm

(but lose 3/8 inch)

4 Feet = 1219.2 mm

3 feet, 11 - 1/4 Inches = 1200 mm

THINK:

4 Feet = 1200 mm

(but lose 3/4 inch)

RULES OF THUMB

1 Inch = 25 mm

4 Inch = 100 mm

6 Inch = 150 mm

8 Inches = 200 mm

12 Inches = 300 mm

2 Feet = 600 mm

4 Feet = 1200 mm

10 Feet = 3000 mm

METRIC

What will change?

What will stay the same?

**Most construction products
WILL NOT CHANGE SIZE**

**They simply will be
RELABELLED**

Only MODULAR products will change:

Drywall, plywood and other sheet products

Suspended ceiling products

Raised flooring

Floor tile

Brick

Block

SUBJECT: DRAWINGS

WHAT WILL CHANGE:

- Units, from feet and inches
To millimeters for all building dimensions
To meters for large site plans and civil engineering drawings
- Scales, from inch-fractions-to-feet (e.g. $1/2" = 1'-0"$) to true ratios (1:20)

WHAT WILL STAY THE SAME:

- Drawing contents

DISCUSSION:

- Metric scales are available from most graphic supply houses. Popular models are Alvin 117 PM, Staedtler-Mars 987-18-1, and Charvos 30-1261.
- NEVER use dual units on drawings. It increases dimensioning time, doubles the chance for errors, makes drawings more confusing, and delays the learning process.
- Centimeters are not used in construction.

SUBJECT: ELEVATIONS AND CONTOUR INTERVALS

WHAT WILL CHANGE:

- Designation from feet (in decimals)
To nearest millimeter, or.
- To meters carried to one, two, or three places
and so noted with an "m" after the number.

WHAT WILL STAY THE SAME:

- graphic conventions for elevation markers and
contour lines.

SUBJECT: SPECIFICATIONS

WHAT WILL CHANGE:

- Units of measure, from inch-pounds to metric

For linear dimensions, use millimeters

For area, use square meters

For volume, use cubic meters

Use other metric units as required

WHAT WILL STAY THE SAME:

- Everything else

DISCUSSION:

- Unit conversion is a matter of rounding within allowable tolerances
- All unit conversions should be checked by a professional

SUBJECT: CEILING SYSTEMS

WHAT WILL CHANGE:

- Grid sizes, lay-in tile and air diffusers, and lighting fixtures

From 2' x 2' to 600 x 600 mm
from 2' x 4' to 600 x 1200 mm

WHAT WILL STAY THE SAME:

- Grid profiles, tile thicknesses, air diffuser capacities, fluorescent tubes
- means of suspension

DISCUSSION:

- Metric ceiling system components are readily available

SUBJECT: DRYWALL, PLYWOOD, RIGID INSULATION (SHEET GOODS)

WHAT WILL CHANGE:

- Width, from 4'-0" to 1200 mm
- Height, from 8'-0" to 2400 mm
from 10'-0" to 3000 mm

WHAT WILL STAY THE SAME:

- Thicknesses, so fire, acoustic, and thermal ratings will not have to be recalculated

DISCUSSION:

- metric drywall is available, with a possible cost penalty for small orders. Metric plywood and rigid insulation may not be available yet. (Plywood is used only in residential and light commercial construction, however)

SUBJECT: BATT INSULATION

WHAT WILL CHANGE:

- Width, from 16" and 24" nominal to 400 mm and 600 mm nominal

OR

- No change, there just will be more of a "friction" fit

WHAT WILL STAY THE SAME:

- Thickness, so thermal ratings will not have to be recalculated

SUBJECT "2-BY-4" STUDS AND OTHER "2-BY" FRAMING (WOOD AND METAL)

WHAT WILL CHANGE:

- Stud and joist spacing, from 16" to 400 mm
from 24" to 600 mm

WHAT WILL STAY THE SAME:

- Cross sections

DISCUSSION:

- "2-by-4s" may keep their name, or perhaps they'll be renamed 40 x 90 mm or, more exactly, 38 x 89 mm. But it's not really important.

SUBJECT: BRICK

WHAT WILL CHANGE:

- Standard brick to 90 x 57 x 190 mm
- Mortar joints from 3/8" to 10 mm
- Brick module from 2' x 2' to 600 mm to 600 mm

WHAT WILL STAY THE SAME:

- Everything else

DISCUSSION:

- Of the 100 or so brick sizes currently made, 5 to 10 are within a millimeter of a metric brick, so the brick industry

SUBJECT: CONCRETE BLOCK

WHAT WILL CHANGE:

- Block sizes to 190 x 190 x 390 mm
- Mortar joints from 1/2" to 10 mm
- Block module from 2' x 2' to 600 x 600 mm

WHAT WILL STAY THE SAME:

- Everything else

DISCUSSION:

- Metric block sizes are too different than current block sizes to fudge. The block industry will have to buy new mold componets.

SUBJECT: CONCRETE

WHAT WILL CHANGE:

- Strength designation from "psi" to megapascals, rounded to the nearest 5 MPa

2500 psi	>	20 MPa
3000 psi	>	25 MPa
3500 psi	>	25 MPa
4000 psi	>	30 MPa
4500 psi	>	35 MPa
5000 psi	>	35 MPa

WHAT WILL STAY THE SAME:

- Strength requirements

SUBJECT: REBAR

WHAT WILL CHANGE:

- Bar sizes, based on cross sectional area, per ASTM A615M.

WHAT WILL STAY THE SAME:

- Composition

DISCUSSION:

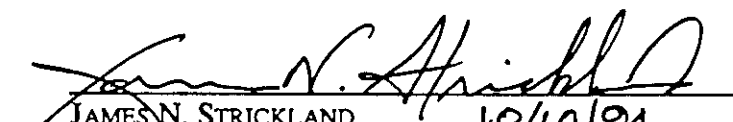
- These sizes are recommended by CRSI and used in Canada

APPROVAL

METRICATION IN A GLOBAL ENVIRONMENT

By J. Aberg

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.


JAMES N. STRICKLAND
Director, Systems Analysis
and Integration Laboratory
10/10/94

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE October 1994		3. REPORT TYPE AND DATES COVERED Technical Memorandum	
4. TITLE AND SUBTITLE Metrication in a Global Environment				5. FUNDING NUMBERS	
6. AUTHOR(S) J. Aberg					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546				10. SPONSORING / MONITORING AGENCY REPORT NUMBER NASA TM-108469	
11. SUPPLEMENTARY NOTES Prepared by Systems Analysis and Integration Laboratory, Science and Engineering Directorate.					
12a. DISTRIBUTION / AVAILABILITY STATEMENT Unclassified—Unlimited				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) A brief history about the development of the metric system of measurement. The need for the U.S. to implement the "SF" metric system in the international markets, especially in the aerospace and general trade. Development of metric implementation and experiences locally, nationally, and internationally are included.					
14. SUBJECT TERMS metrication, "SF" the international system of measurement, hard and soft conversion				15. NUMBER OF PAGES 80	
				16. PRICE CODE NTIS	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited		